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The Hypersonic Aerodynamic Characteristics of the Gemini Re-Entry Module Based on a Statistical Analysis of Wind Tunnel Test Data

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Prepared by BERNARD M. PERSHING
Applied Mechanics Division

June 1968

Prepared for DEPUTY DIRECTOR
MANNED ORBITING LABORATORY PROGRAM
MOL SYSTEMS OFFICE, OSAF
HEADQUARTERS, SPACE SYSTEMS DIVISION
Air Force Unit Post Office
Los Angeles, California 90045

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Bernard M. Pershing

Bernard M. Pershing
Fluid Mechanics Department
Applied Mechanics Division

Reviewed by

for R. W. Rector

R. W. Rector
Management Systems and Administration
MOL Systems Engineering Office

Approved by

W. F. Radcliffe

W. F. Radcliffe, Director
Engineering Sciences Subdivision
Applied Mechanics Division

W. D. Pittman

W. D. Pittman, Director
MAC Office
Engineering Directorate
MOL Systems Engineering Office

[redacted]

ABSTRACT

A set of hypersonic aerodynamic characteristics has been obtained for the Gemini re-entry module by a least squares curve fit of the appropriate ground test data to equation forms which are based on the related flow phenomena and simulation requirements. Correlation of flight test α_T and $(L/D)_T$ with predicted values based on the curve fit set of characteristics is satisfactory in the low α_T range (less than 8 deg) but deteriorates with increased α_T. This deterioration is shown to be due to differences in the flight and predicted values of C_N and $C_{m_{ref}}$.

Based on these results it is concluded that current hypersonic ground test facilities produce Gemini B afterbody aerodynamic forces of questionable accuracy due to their lack of total enthalpy simulation. This deficiency can result in differences of 10 to 15 percent between predicted and flight measured trim characteristics. Further refinement of vehicle aerodynamic characteristics can be achieved only through use of flight test data.

It is recommended that the sensitivity of Gemini B system requirements to tolerances in predicted aerodynamic characteristics be established through appropriate systems studies and, if warranted, the existing NASA flight test data be re-examined and applied to the refinement of these characteristics.

ACKNOWLEDGMENT

The author would like to acknowledge the work of Philip H. Young of the Aerospace Computation and Data Processing Center in the preparation of the least squares curve fit and statistical analysis program used in this study.

NOMENCLATURE

α	angle of attack, deg
C_A	axial force coefficient; $F_A/q\,\frac{\pi D^2}{4}$
$C_{m_{ref}}$	pitching moment coefficient; $M_{ref}/q\,\frac{\pi D^3}{4}$
C_N	normal force coefficient; $F_N/q\,\frac{\pi D^2}{4}$
$C_{P_{max}}$	stagnation pressure coefficient behind a normal shock
D	diameter, ft
e	center of gravity lateral offset, in.
h	altitude, ft
H_o	total enthalpy, Btu/lb
k	constant
L/D	lift/drag ratio
M	Mach number
q	dynamic pressure, lb/ft^2
Re_{∞_D}	free stream Reynolds number based on vehicle diameter
Re_{1_D}	Reynolds number behind normal shock based on vehicle diameter
u or v	velocity, ft/sec

Subscripts

$(\ )_T$	denotes trim
$(\ )_\infty$	denotes free stream
$(\ )_N$	denotes Newtonian
$(\ )_{AB}$	denotes afterbody
$(\ )_{FB}$	denotes forebody

CONTENTS

FIGURES

FIGURES (Continued)

TABLES

1. INTRODUCTION

The hypersonic aerodynamic characteristics of the Gemini re-entry module must be known to some acceptable level of accuracy for purposes of system design and operational planning. The NASA Gemini characteristics were initially established by ground facility tests in 1962 (Refs. 1 and 2) and were later modified by GT-2, -3, and -4 flight test data. The Gemini B aerodynamic characteristics were independently established in 1965 by a least squares curve fit of the test data of Ref. 3 to power series in M_{∞} and α.

It is well known that current ground test facilities lack total simulation capability of the re-entry environment (Ref. 4). This, combined with unknown sting effects and the transient character of hypersonic test shots, raises the question of the accuracy of aerodynamic characteristics based wholly on ground facility data. Furthermore, the data scatter of hypersonic facilities is large. These factors combine to impose severe penalties on vehicle design and/or operational capability when the system is subjected to dispersion analyses.

Motivated by these considerations, a re-examination of the predicted hypersonic aerodynamic characteristics of the Gemini B re-entry module was undertaken with the objectives (1) of defining a consistent set of minimum tolerance aerodynamic characteristics based on ground facility test data, and (2) attempting to draw conclusions as to the capability of predicting full-scale aerodynamics from ground facility tests by comparison with available flight data.

2. FLIGHT AND GROUND TEST FLOW SIMULATION

The velocity-altitude plots of GT-2, -3, -4, -5, HST and estimated Gemini B full and zero lift abort boundary re-entry trajectories are shown in Figure 1. These trajectories serve as a qualitative definition of the Gemini operational v-h envelope. The corresponding boundaries for free stream Reynolds number Re_{∞_D}, Reynolds number behind a normal shock Re_{1_D}, total enthalpy H_o, and stagnation pressure coefficient behind a normal shock $C_{P_{max}}$, have been computed using the real gas tables of Ref. 5 and are shown in Figures 2, 3, and 4.

A comparison of these flight boundaries with wind tunnel test values is also shown in Figures 2 and 3. The data represent the major wind tunnel tests performed on the NASA Gemini and Gemini B re-entry module (Refs. 1 through 3 and 6 through 14). A list of these tests and their Mach number, Reynolds number, and enthalpy ranges is presented in Table I. Reference 14, although not a Gemini configuration, is included in Table I as it is geometrically similar and provides data in a Mach number range unavailable elsewhere. It is seen from Figure 2 that in the hypersonic range, Re_{1_D} is not simulated even though the test and flight values of Re_{∞_D} may be matched. This disparity is a direct consequence of the low H_o levels of ground test facilities. At the higher Mach numbers, test section H_o is an order of magnitude less than flight values (Figure 3).

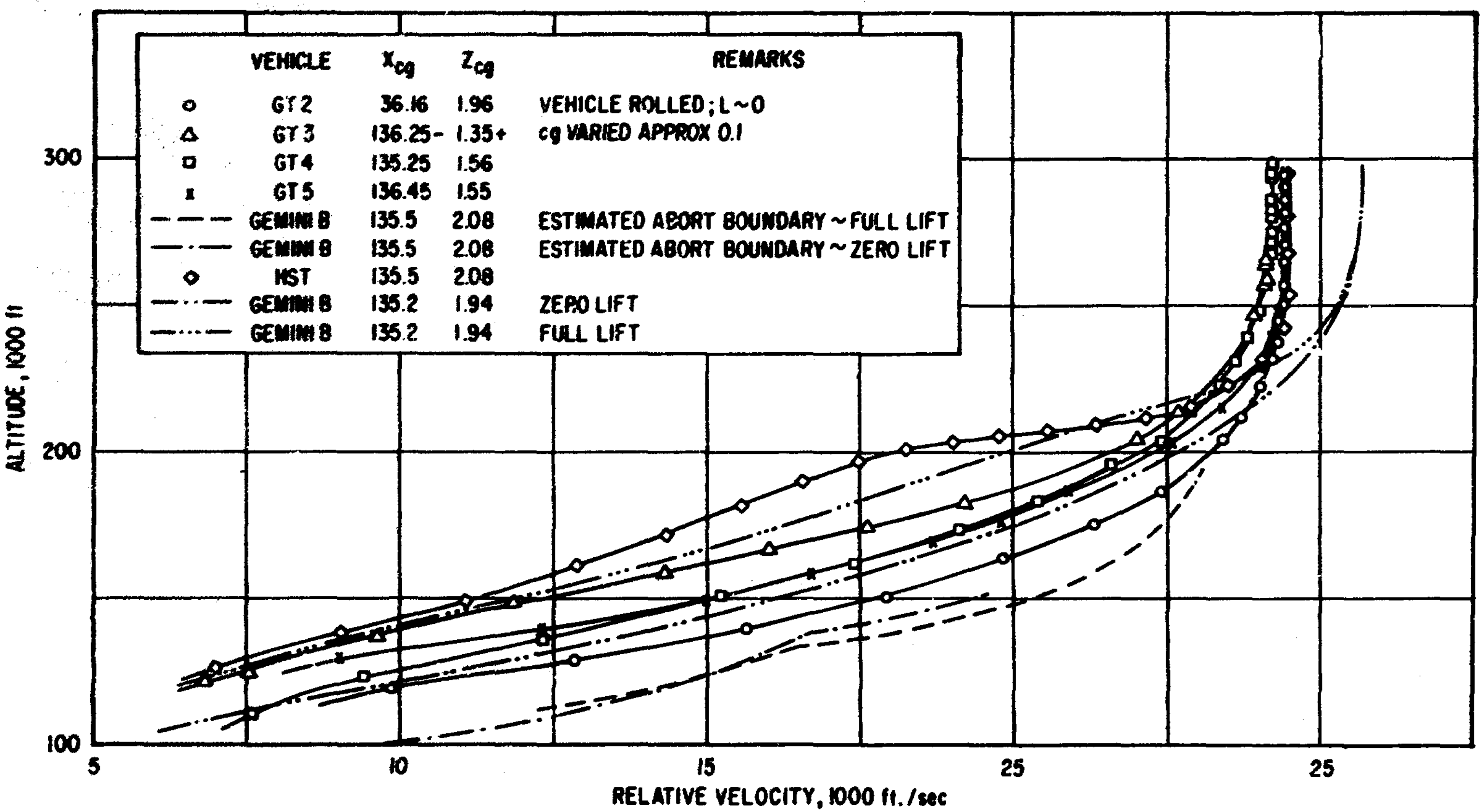

Figure 1. Gemini Capsule Re-entry Trajectory

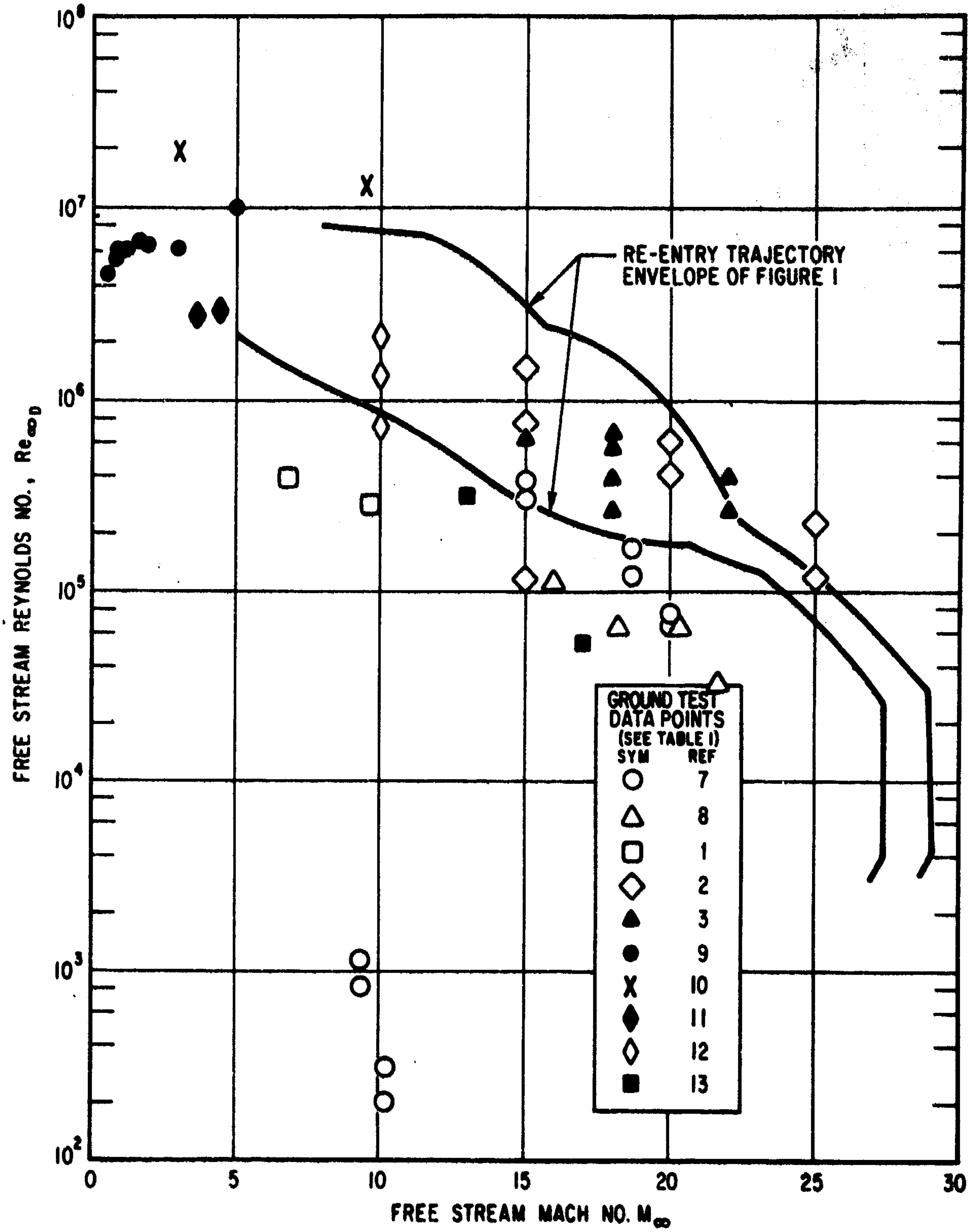

Figure 2a. Re-entry Trajectory Free Stream Reynolds Number Re_{∞_D}

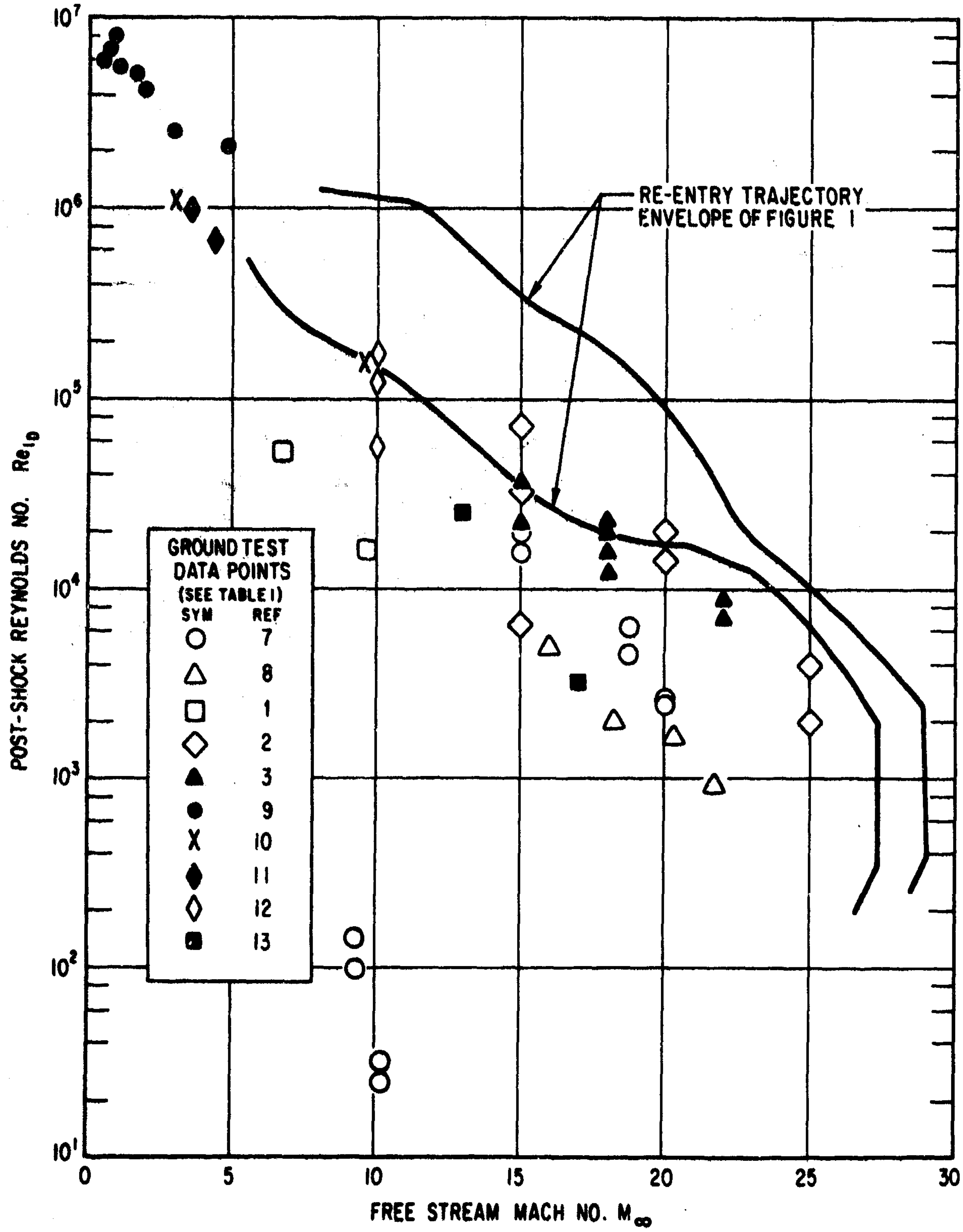

Figure 2b. Re-entry Trajectory Post-Shock Reynolds Number Re_{1_D}

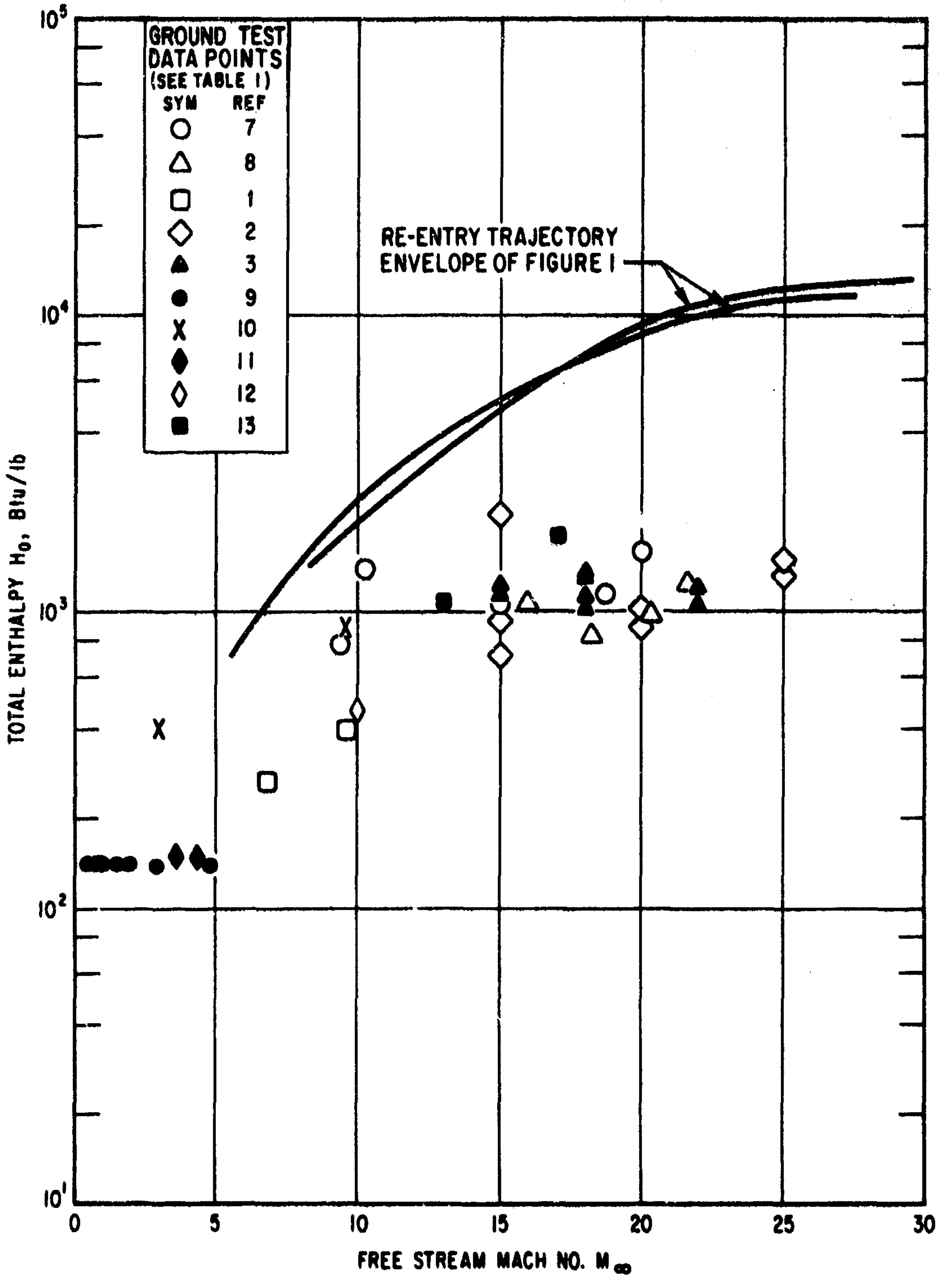

Figure 3. Re-entry Trajectory Total Enthalpy H_0

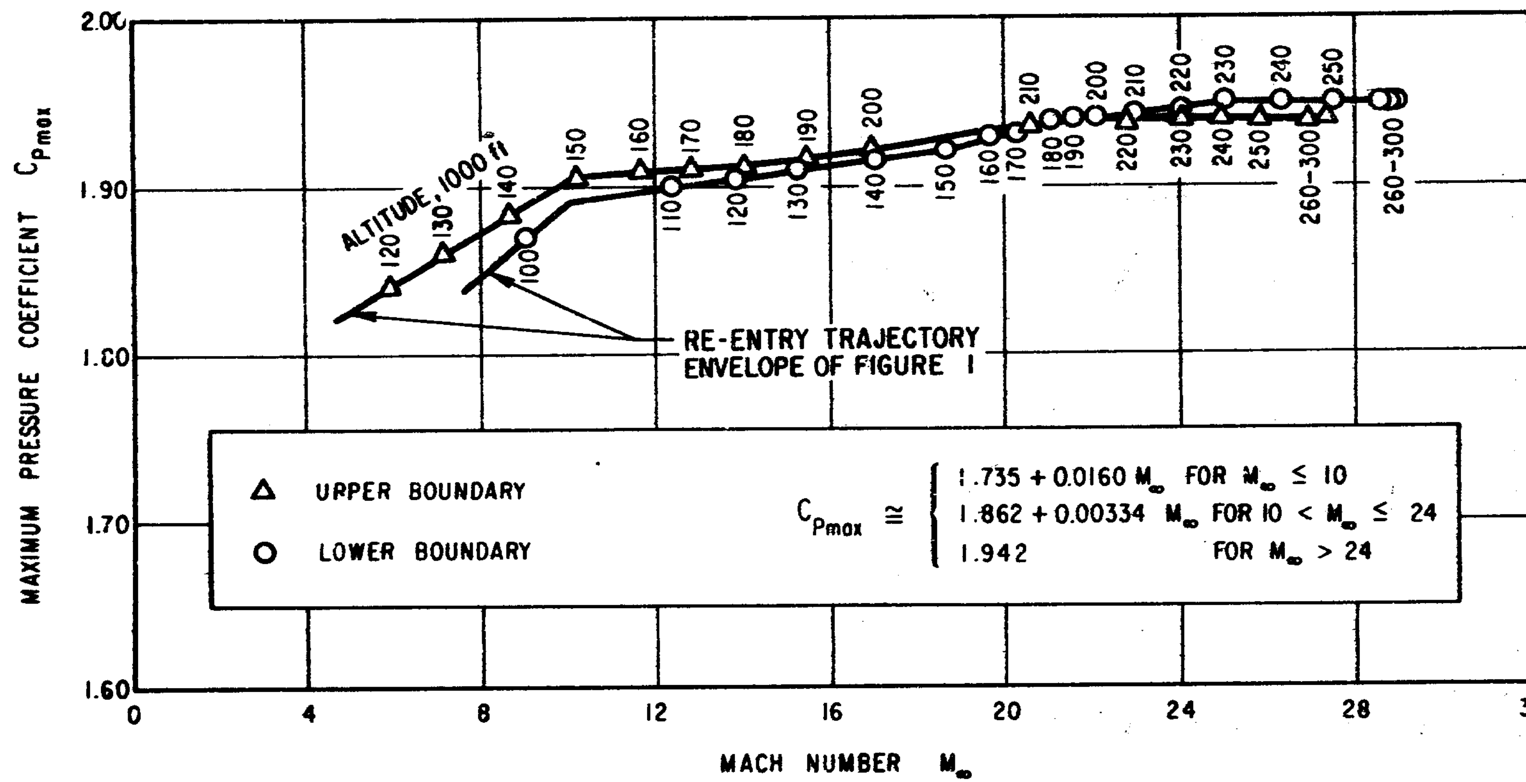

Figure 4. Re-entry Trajectory Maximum Pressure Coefficient $C_{P_{max}}$

Table I. Major Gemini Re-entry Module Wind Tunnel Tests (Sheet 1 of 2)

Facility	Mach No.	Reynolds No. $Re_D \times 10^{-5}$ Free Stream	Reynolds No. $Re_D \times 10^{-5}$ Post Shock	Total Enthalpy Btu/lb	Type of Test	Comments
AEDC Tunnels L and F	9.37 10.15 15.0 18.7 20.0	0.008 to 0.012 0.002 to 0.003 3.0 to 3.7 1.25 to 1.77 0.65 to 0.74	0.0010 to 0.0015 0.00025 to 0.00032 0.16 to 0.20 0.045 to 0.065 0.025	780 1400 1075 1180 1600	Force and moment	Ref. 7
Aerospace Hypersonic Shock Tunnel	16.0 18.2 20.3 21.6	1.12 0.625 0.625 0.31	0.050 0.02 0.016 0.0085	1090 830 1000 1230	Force and moment	Ref. 8
NASA Langley Hypersonic	6.8 9.6	3.82 1.80	0.52 0.15	270 400	Force and moment	Ref. 1
MAC HIT Facility	15 20 25	1.13 to 15 4.0 to 6.0 1.18 to 2.25	0.067 to 0.76 0.15 to 0.20 0.02 to 0.04	2150 to 725 1010 to 960 1500 to 1340	Force and moment	Ref. 2
MAC HIT Facility	15 18 22	4.0 to 6.75 2.7 to 6.8 2.7 to 4.0	0.24 to 0.39 0.13 to 0.24 0.07 to 0.09	1250 to 1100 1350 to 1050 1220 to 1075	Force and moment	Ref. 3
MAC Polysonic Facility	0.50 to 4.86	45 to 105	45 to 21.5	140	Force and moment	Ref. 9
Ames Hyper-velocity Free Flight Fac	3.0 9.5	20 13.5	10.8 1.7	400 875	Force and moment	Ref. 10
Langley Unitar- Tunnel	3.51 4.44	28 28	9.75 6.9	150 150	Pressure and heat transfer	Ref. 11
AEDC Tunnels B and C	10	5.4 to 16	0.43 to 1.25	460	Pressure and heat transfer	Ref. 12

Table I. Major Gemini Re-entry Module Wind Tunnel Tests (Sheet 2 of 2)

Facility	Mach No.	Reynolds No. $Re_D \times 10^{-5}$ Free Stream	Reynolds No. $Re_D \times 10^{-5}$ Post Shock	Total Enthalpy Btu/lb	Type of Test	Comments
Cornell Hypersonic Shock Tunnel	13 17	3.15 0.53	0.25 0.03	1080 1080	Pressure and heat transfer	Ref. 13
MAC HIT Facility	15				Force and moment	Ref. 6
Ames Hyper-velocity Free Flight Tunnel	35	1.21	0.075	18,200	Force and moment	Ref. 14 Apollo-like afterbody. Sharp corner Heat shield

3. AERODYNAMIC CHARACTERISTICS CURVE FIT

Curves of the Gemini re-entry module hypersonic aerodynamic characteristics have been fitted to those force and moment test data of Table I with Mach number 6.8 and greater by a multiple linear regression least squares technique. In this procedure, the aerodynamic coefficients were assumed to be of the form

$$C_A = \sum_{i=0}^{n} a_i g_i; \quad C_N = \sum_{i=0}^{n} b_i g_i; \quad C_{m_{ref}} = \sum_{i=0}^{n} c_i g_i \tag{1}$$

where the g_i are independent variables and the a_i, b_i, and c_i are the partial regression coefficients determined by the least squares fit. The g_i cannot be arbitrary if the curve fits are to be meaningful; they must be chosen from a consideration of the physics involved. The following section discusses the g_i used and the basis for their selection and presents the resultant curve fits.

3.1 GENERAL CONSIDERATIONS

The Gemini re-entry module is shown in Figure 5 along with the notation used in this study. Restricting the range of interest to moderate angle of attack, say $|\alpha| < 30$ deg and $M_\infty > 6$, it is clear that Newtonian theory is applicable to the forebody and the Mach number independence principle is applicable to the over-all vehicle. The latter combined with the assumption that the flow solution is unique for any M_∞ requires that test data for similar configurations form a clearly defined variation with M_∞ and that this variation be a weak function of M_∞ which approaches a limit uniformly as $M_\infty \to \infty$. The fluid properties behind the bow shock serve as the boundary conditions for the flow about the vehicle. The afterbody wake flow is therefore properly correlated with Re_{1_D} while the forebody flow field is essentially viscous independent.

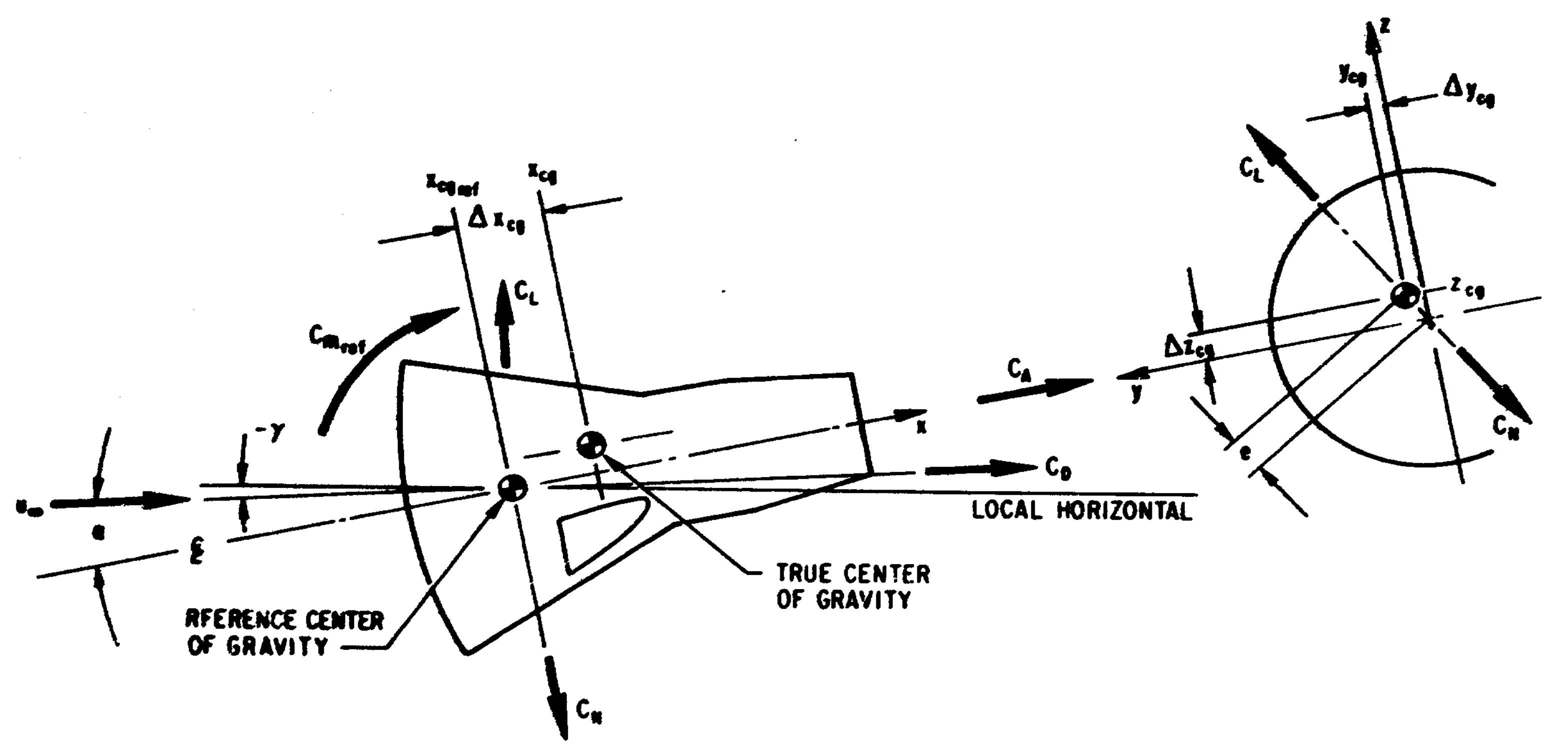

Figure 5. Gemini Re-entry Module Coordinate System and Notation

3.2 EQUATION FORMS

3.2.1 Axial Force Coefficient

It is assumed that C_A varies smoothly with α and is little affected by changes in afterbody flow geometry. Furthermore, C_A is restricted to be an even function in α by axial symmetry. Newtonian analysis applied to Gemini type forebody geometry yields

$$C_{A_N} = C_{P_{max}}(k_1 - k_2 \sin^2\alpha) \tag{2a}$$

or

$$C_{A_N}/C_{A_{N_{\alpha=0}}} = 1 - k_2/k_1 \sin^2\alpha \tag{2b}$$

where k_1 and k_2 are functions of forebody geometry. Correlation of the hypersonic test data of T ble I shows close conformity to the $\sin^2\alpha$ variation of Eq. (2b) with $(k_2/k_1)/(k_2/k_1)_N \sim 0.9 \pm 0.2$ over the Mach number range. Pressure data of Table I show that for $M_\infty > 7$, the afterbody contribution to C_A is less than 2 percent. Accordingly, the equation form chosen for the C_A data curve fit is

$$C_A = C_{P_{max}}[(a_0 + a_1 M_\infty^{-1} + a_2 M_\infty) - (a_3 + a_4 M_\infty^{-1} + a_5 M_\infty)\sin^2\alpha] \tag{3}$$

where Cp_{max} is a piecewise linear approximation of the operational boundary Cp_{max} (Figure 4). The rational functions in M_∞ account for the possible variations of k_1 and k_2 with free stream Mach number, their forms being obtained from a consideration of the similarity laws governing hypersonic expansion flow.

3.2.2 Normal Force and Pitching Moment Coefficient

Both forebody and afterbody contributions to C_N and $C_{m_{ref}}$ are assumed present. The forebody contributions are expected to vary smoothly with α while the afterbody contributions may show variations in form due to changes in wake geometry with α. Such variations might be expected at $\alpha \sim 13$ deg when the afterbody starts to see the oncoming flow and at $\alpha \sim 35$ deg when the bow shock impinges on the aft section. Total C_N and $C_{m_{ref}}$ are restricted to be odd functions in α by axial symmetry.

The forebody contributions as given by Newtonian theory are

$$C_{N_{FB}} = C_{P_{max}} k_3 \sin\alpha\cos\alpha \qquad (3)$$

$$C_{m_{ref_{FB}}} = C_{P_{max}} k_4 \sin\alpha\cos\alpha \qquad (4)$$

where k_3 is a function of forebody geometry, and k_4 is a function of forebody geometry and moment reference center location.

The functional form of the afterbody contribution cannot a priori be determined. In the absence of adequate separated flow theory, an empirical approach was taken based on the limited afterbody pressure data available. It was assumed that the incremental circumferential pressure distribution over the afterbody can be approximated by one which is self-similar, that is, a function of azimuth angle only. With our using the test data of Refs. 15 and 16 to define this distribution and the data of Table I for the variation of the windward ray pressure distribution with α, a numerical integration was performed to obtain the afterbody contributions $C_{N_{AB}}$ and $C_{m_{ref_{AB}}}$. The results are shown in Figure 6 for $M_\infty = 10$, 13, and 17.

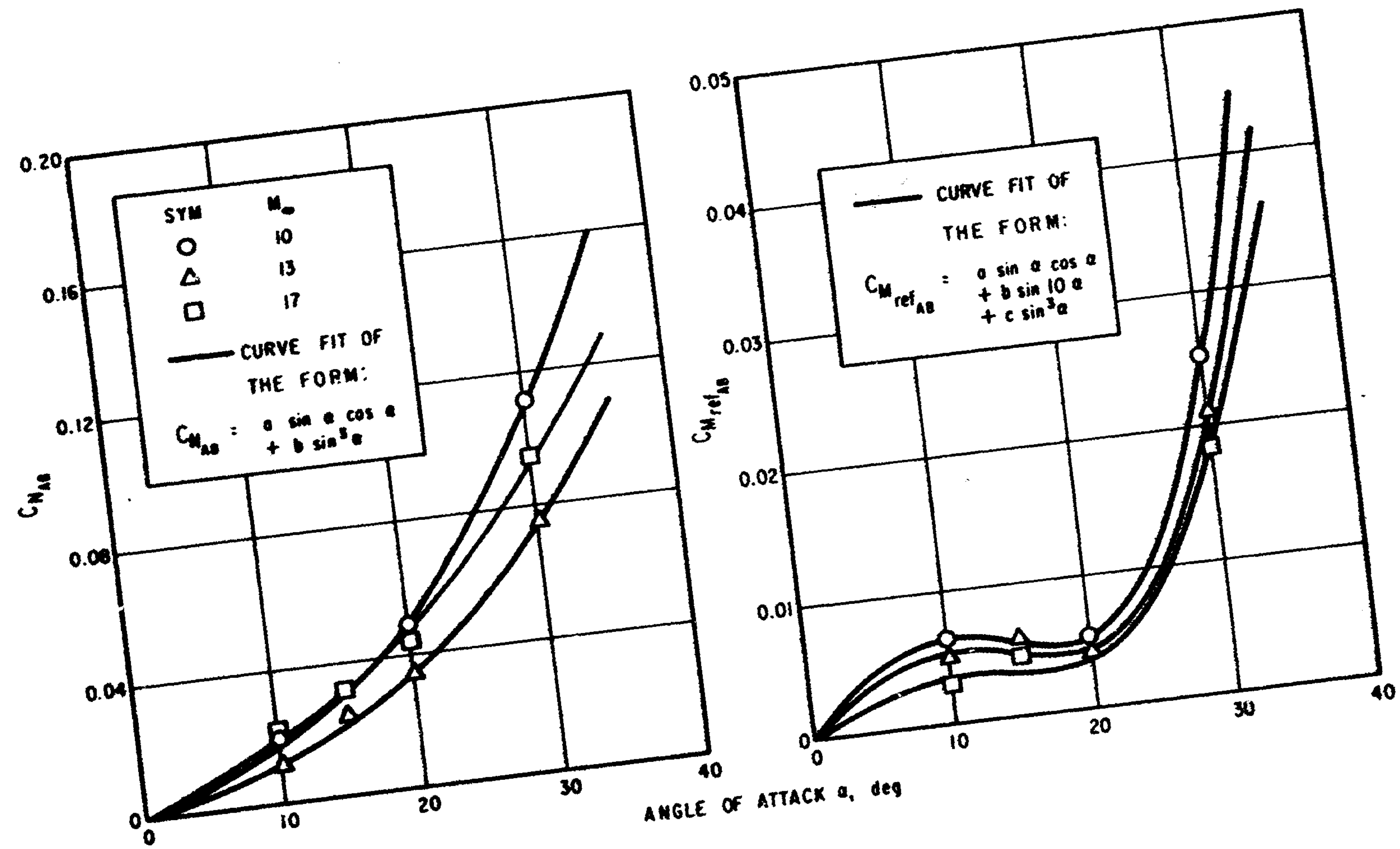

Figure 6. Computed Afterbody Contribution, $C_{N_{AB}}$ and $C_{m_{ref_{AB}}}$

Curves have been fit to the computed points of Figure 6 using equations of the form

$$C_{N_{AB}} = k_5 \sin\alpha\cos\alpha + k_6 \sin^3\alpha \qquad (5)$$

$$C_{m_{ref_{AB}}} = k_7 \sin\alpha\cos\alpha + k_8 \sin(n\alpha) + k_9 \sin^3\alpha \qquad (6)$$

The functional forms of Eqs. (5) and (6) were arrived at by inspection of the data and the desire to maintain consistency with Eqs. (3) and (4). The $\sin(n\alpha)$ term of Eq. (6) is included to account for the inflection of the $C_{m_{ref_{AB}}}$ data around $\alpha \sim 15$ deg. The value n = 10 is used for the curves of Figure 6.

A buildup of estimated total C_N and $C_{m_{ref}}$ consisting of Newtonian forebody contributions, Eqs. (3) and (4), and the afterbody contributions defined by the $M_\infty = 17$ curve of Figure 6 are shown in Figure 7. The Mach 15 test data of Refs. 2 and 3 are also shown for comparison. Correlation appears quite good considering the approximations underlying the estimated buildup. Of particular interest is the nontrivial contribution of the afterbody to total estimated C_N and $C_{m_{ref}}$ and $\sin(n\alpha)$-like behavior of the test data, clearly present in the $C_{m_{ref}}$ data and to a lesser degree in the C_N data. The $\sin(n\alpha)$ term is therefore considered necessary in a comprehensive analytic description of both $C_{N_{AB}}$ and $C_{m_{ref_{AB}}}$.

Based on the above considerations, the equation forms chosen for use in the C_N and $C_{m_{ref}}$ curve fit are

$$C_N = C_{P_{max}} [(b_0 + b_1 M_\infty^{-1} + b_2 M_\infty) + (b_6 + b_7 M_\infty^{-1} + b_8 M_\infty)\sin\alpha\cos\alpha$$

$$+ (b_9 + b_{10} M_\infty^{-1} + b_{11} M_\infty)\sin(n\alpha) + (b_{12} + b_{13} M_\infty^{-1} + b_{14} M_\infty)\sin^3\alpha] \qquad (7)$$

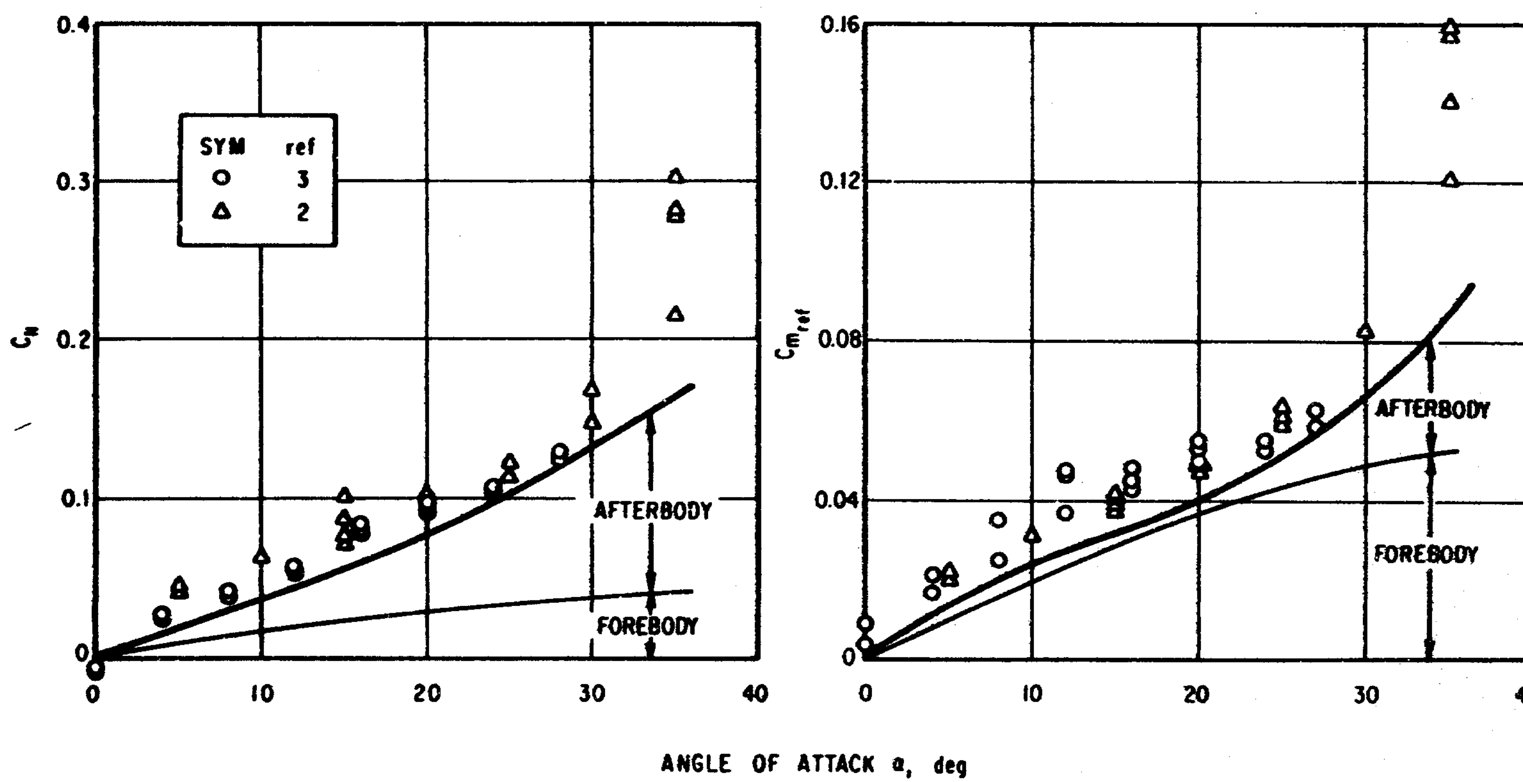

Figure 7. Build-up of C_N and $C_{m_{ref}}$

$$C_{m_{ref}} = C_{P_{max}} [(c_0 + c_1 M_\infty^{-1} + c_2 M_\infty) - (c_6 + c_7 M_\infty^{-1} + c_8 M_\infty) \sin\alpha\cos\alpha$$

$$+ (c_9 + c_{10} M_\infty^{-1} + c_{11} M_\infty) \sin(n\alpha) + (c_{12} + c_{13} M_\infty^{-1} + c_{14} M_\infty) \sin^3\alpha] \tag{8}$$

where as in Eq. (3) the rational functions in M_∞ account for possible variations of the k_i with free stream Mach number.

3.3 GEMINI RE-ENTRY MODULE AERODYNAMIC CHARACTERISTICS

A multiple linear regression least squares technique has been used to fit Eq. (3) and Eqs. (7) and (8) with n = 10 to the applicable test data of Table I. The value n = 10 was chosen as that integer $4 \le n \le 15$ which yielded a minimum for the standard error of estimate for C_N and $C_{m_{ref}}$. The resultant set of partial regression coefficients a_i, b_i, c_i is listed in Table II. The aerodynamic characteristics defined by Table II are presented graphically in Figure 8 and numerically in the Appendix and are considered to be a consistent estimate of the Gemini re-entry module hypersonic aerodynamics from a statistical and physical standpoint.

The low Mach number data of Ref. 9 are also shown in Figure 8 and Table III for completeness and the data for $M_\infty = 30$ are included to facilitate interpolating in the range $25 < M_\infty < 30$. Note, however, that this region of maximum M_∞ shown in the v-h envelope of Figure 2, corresponds to h > 260,000 ft where the assumption of continuum flow begins to break down and predictions based on transitional and free molecular flow theories are required.

Table II. Partial Regression Coefficients and Aerodynamic Characteristics

Curve Fit

$$C_A = C_{P_{max}} \sum_{i=0}^{14} a_i g_i; \quad C_N = C_{P_{max}} \sum_{i=0}^{14} b_i g_i; \quad C_{m_{ref}} = C_{P_{max}} \sum_{i=0}^{14} c_i g_i$$

i	a_i	b_i	c_i	g_i
0	0.736501	-0.042360	0.027106	1
1	0.800452	0.190849	-0.163643	M_∞^{-1}
2	0.0066785	0.0016558	-0.0008677	M_∞
3	0.094915	0	0	$\sin^2\alpha$
4	-4.074827	0	0	$M_\infty^{-1}\sin^2\alpha$
5	-0.0364345	0	0	$M_\infty \sin^2\alpha$
6	0	0.153436	-0.034520	$\sin\alpha\cos\alpha$
7	0	0.646552	0.841380	$M_\infty^{-1}\sin\alpha\cos\alpha$
8	0	-0.0010756	0.0033979	$M_\infty \sin\alpha\cos\alpha$
9	0	0.040932	-0.006345	$\sin(10\alpha)$
10	0	-0.173935	0.089669	$M_\infty^{-1}\sin(10\alpha)$
11	0	-0.0014653	0.0002452	$M_\infty \sin(10\alpha)$
12	0	1.093180	0.030490	$\sin^3\alpha$
13	0	-4.767849	0.928086	$M_\infty^{-1}\sin^3\alpha$
14	0	-0.0336268	0.0003128	$M_\infty \sin^3\alpha$

$$C_{P_{max}} = \begin{cases} 1.735 + 0.0160\, M_\infty & \text{for } M_\infty \le 10 \\ 1.862 + 0.00334\, M_\infty & \text{for } 10 < M_\infty \le 24 \\ 1.942 & \text{for } M_\infty > 24 \end{cases}$$

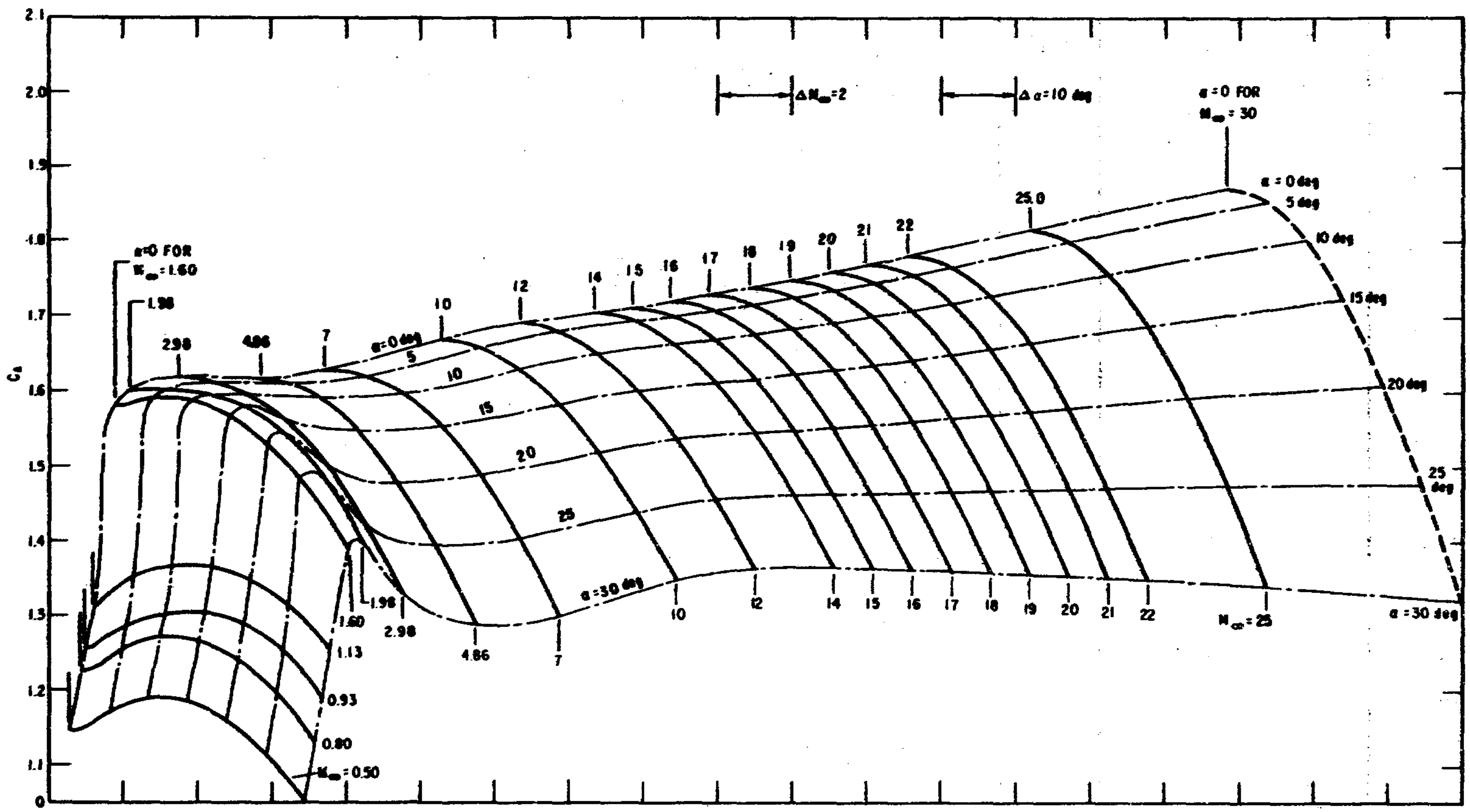

Figure 8a. Axial Force Coefficient C_A, Re-entry Configuration

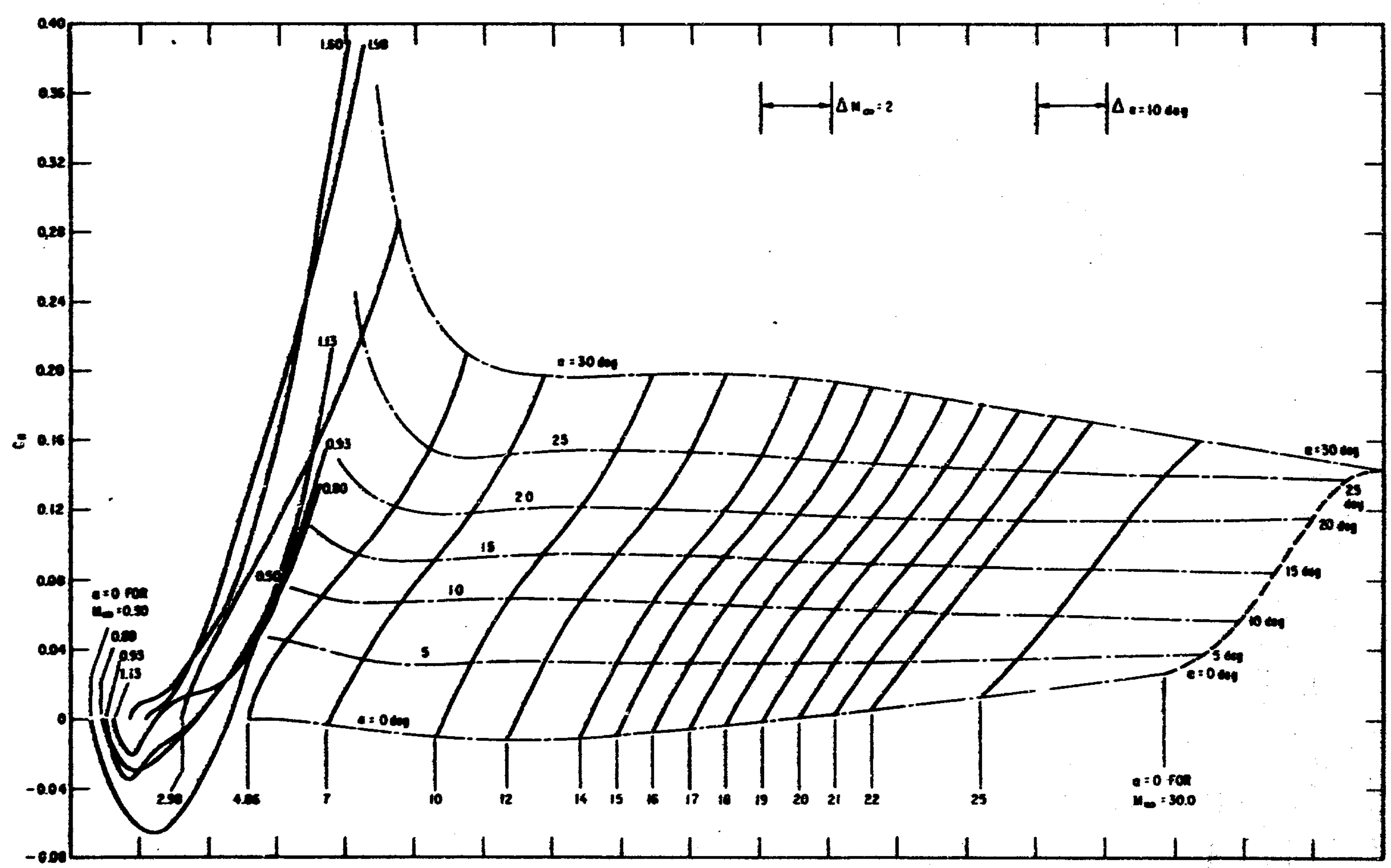

Figure 8b. Normal Force Coefficient C_N, Re-entry Configuration

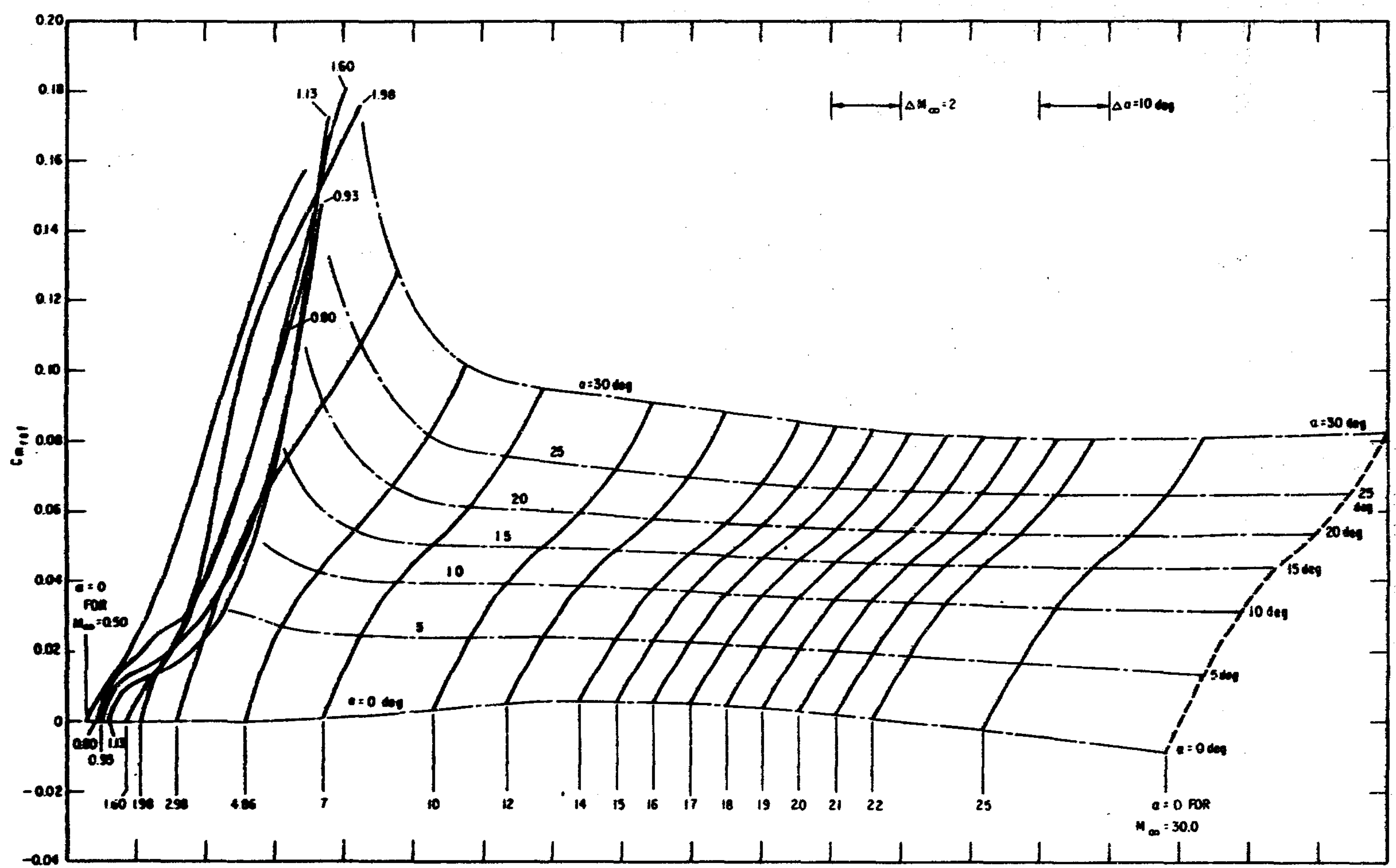

Figure 8c. Pitching Moment Coefficient $C_{m_{ref}}$, Re-entry Configuration

4. AERODYNAMIC CHARACTERISTICS STATISTICAL PROPERTIES

The statistical properties of the least squares curve fit of Section 3.3 are summarized in Table III and Figure 9. Table III presents the summation of the residuals and standard error of estimate of C_A, C_N, and $C_{m_{ref}}$ about the regression plane and the correlation coefficients $\rho_{C_A C_N}$, $\rho_{C_A C_{m_{ref}}}$ and $\rho_{C_N C_{m_{ref}}}$. The differences in sample size are due to using data points in the analysis which did not always consist of C_A, C_N, $C_{m_{ref}}$ triplets. The 99.7 percent confidence limits as computed by the method of Ref. 17 are shown in Figure 9 in carpet plot format as a function of M_∞ and α.

Table III. Statistical Properties of the Aerodynamic Characteristics Curve Fit

Item	Value	Sample Size
Summation of the residuals, r_{C_i} $r_{C_i} = \sum_{j=1}^{n} (C_{i_j} - C_{i_j}')$ (See footnote)	$r_{C_A} = 1.27 \times 10^{-10}$	256
	$r_{C_N} = 6.11 \times 10^{-12}$	247
	$r_{C_{m_{ref}}} = -0.238 \times 10^{-12}$	206
Standard error of estimate, s_{C_i} $s_{C_i} = \left\{ \frac{\sum_{j=1}^{n} (C_{i_j} - C_{i_j}')^2}{n - k - 1} \right\}^{1/2}$	$s_{C_A} = 0.1022$	256
	$s_{C_N} = 0.0245$	247
	$s_{C_{m_{ref}}} = 0.00685$	206
Correlation coefficient, $\rho_{C_i C_h}$ $\rho_{C_i C_h} = \frac{\sum_{j=1}^{n} (C_{i_j} - C_{i_j}')(C_{h_j} - C_{h_j}')}{(n - k - 1)\, s_{C_i}\, s_{C_h}}$	$\rho_{C_A C_N} = 0.2009$	195
	$\rho_{C_A C_{m_{ref}}} = 0.1205$	200
	$\rho_{C_N C_{m_{ref}}} = 0.0969$	192

C_{i_j} = j^{th} test point

C_{i_j}' = Predicted value of C_i corresponding to M_{∞_j} and α_j

n = Total number of test points

k = Degrees of freedom in curve fit equation

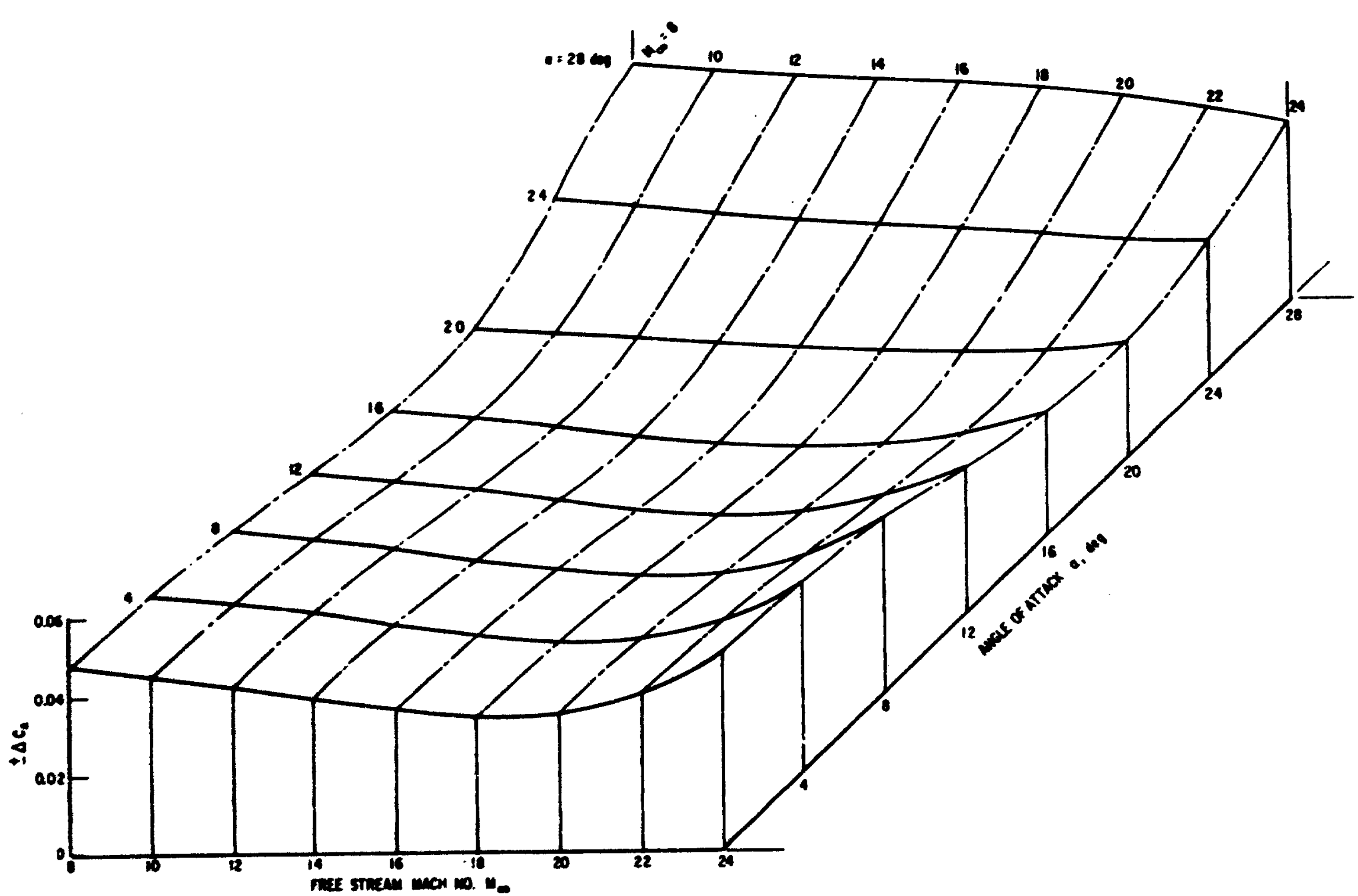

Figure 9a. Ninety-nine Percent Confidence Interval for C_A

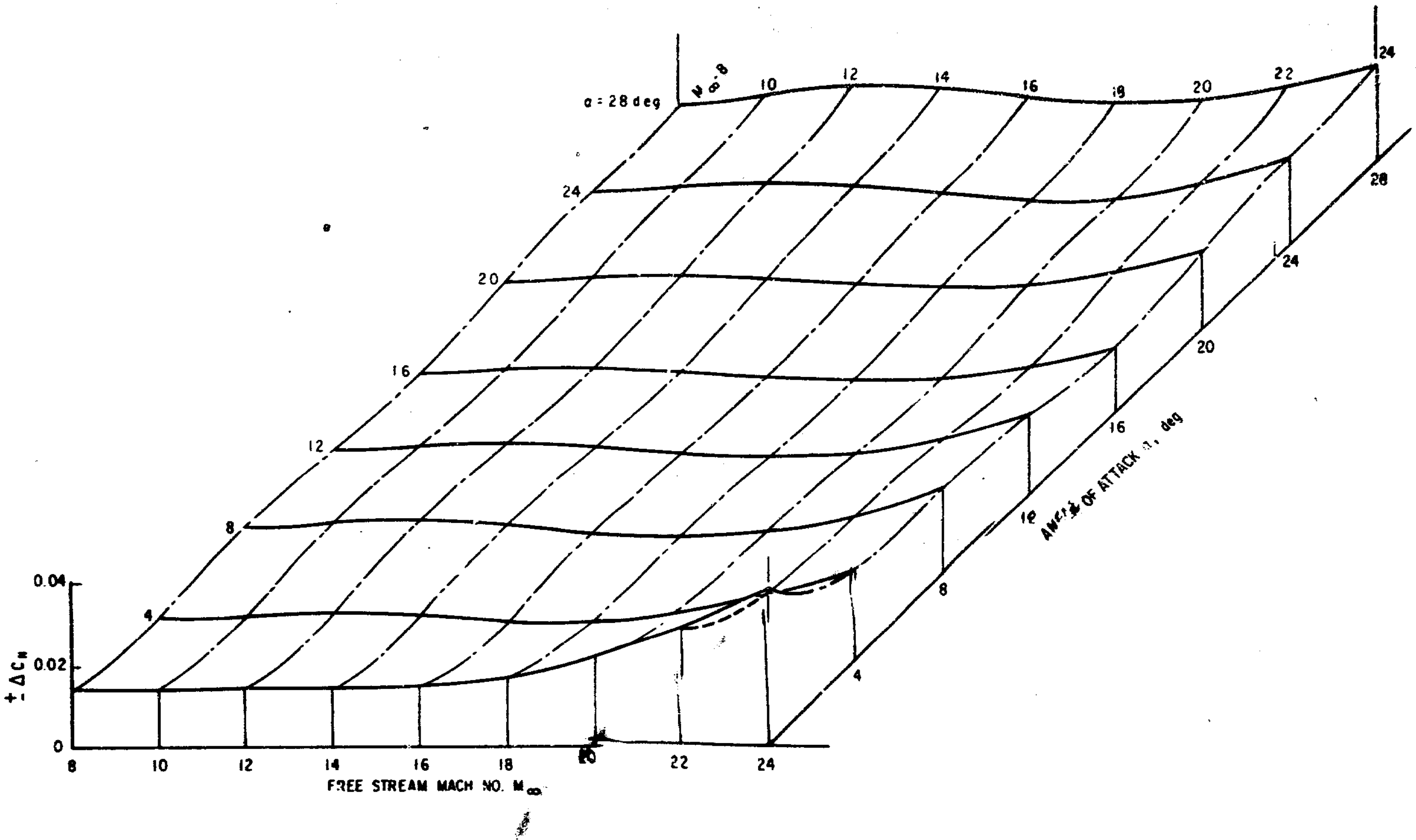

Figure 9b. Ninety Percent Confidence Interval for C_N

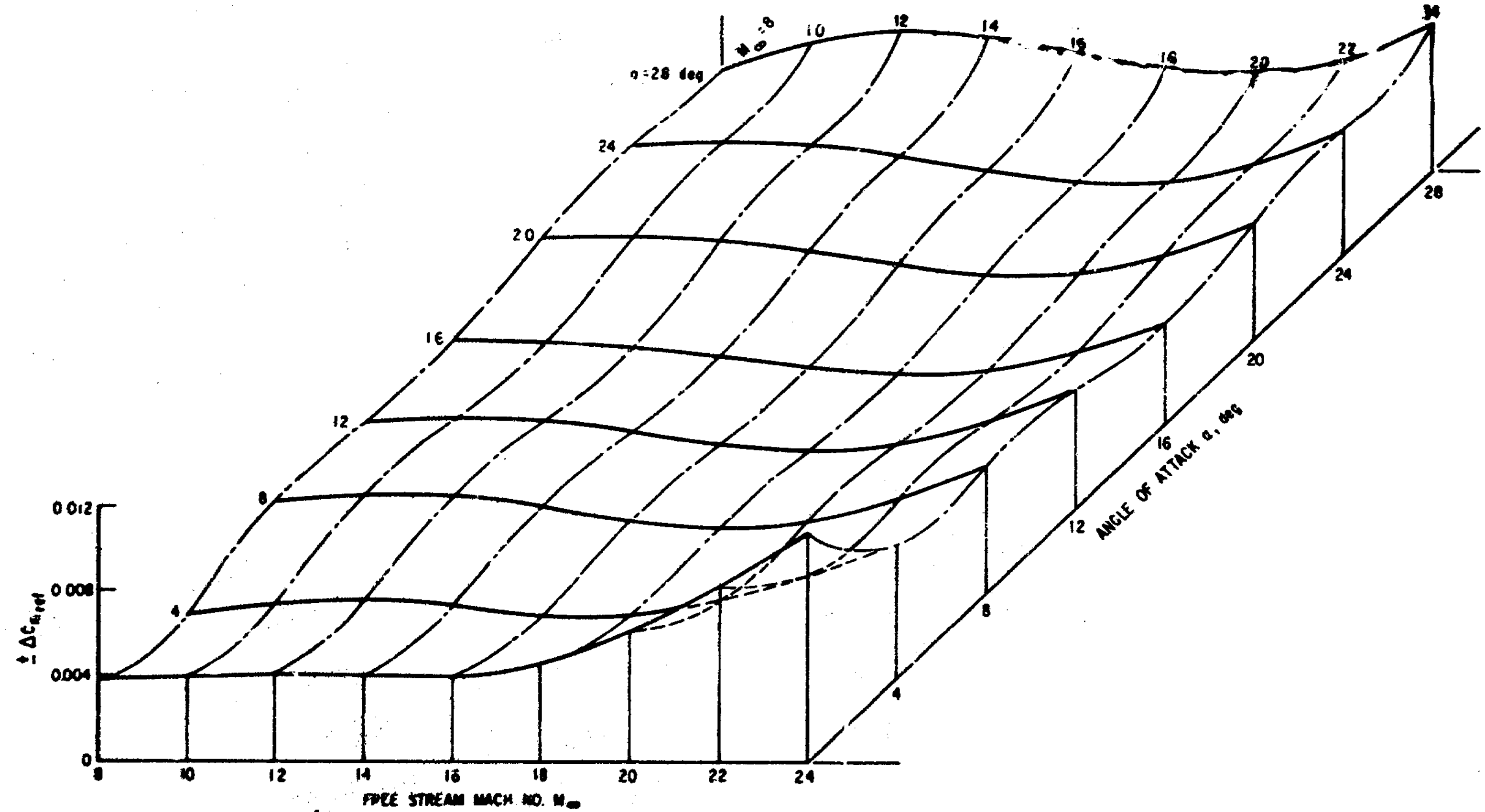

Figure 9c. Ninety-nine Percent Confidence Interval for $C_{m_{ref}}$

5. CORRELATION WITH FLIGHT TEST DATA

5.1 TRIM AERODYNAMICS, α_T AND $(L/D)_T$

The predicted trim characteristics α_T and $(L/D)_T$ based on the aerodynamics of the Appendix are compared with flight measured values in Figure 10 for the GT-2, -3, -4, -5, -8, -10, -11, and -12. Also shown are the predicted values for Gemini B based on the data of Ref. 3. With the exception of GT-5, Figure 10d, the predicted curves of both α_T and $(L/D)_T$ tend to underestimate the flight measured values. A cross-plot of these data are shown in Figure 11. Here, α_T and $(L/D)_T$ are plotted versus lateral c.g. offset e for the two cases, $M_\infty = 16$ and 22. The flight values shown are from a least squares fit of the Figure 10 data to equations of the form $\sum_{i=-2}^{2} k_i M_\infty^i$. All data of Figure 11 are corrected to the longitudinal c.g. position, $X_{cg} = 136$, to permit comparison on the basis of variation in e alone. The flight data with the exception of GT-5 fall into bands whose widths correspond to a = 0.1 in. displacement in e. The GT-5 flight data points fall about 0.1 in. to the right of the data bands. The re-entry c.g. positions of the NASA Gemini spacecraft were obtained in postflight analysis by weighing the recovered capsule and correcting for deployed chutes, water, blankets, crew, propellant, etc. It is not unreasonable that this procedure can, on occasion, result in errors of the order ± 0.1 in. Therefore, it is suggested that the anomalous behavior of the GT-5 flight data in Figures 10d and 11 is the result of an incorrectly estimated re-entry e and that a more probable value is of the order 1.42 in.

The predicted trim characteristics are also shown in Figure 11. Those based on the Ref. 3 data underestimate flight measured α_T and $(L/D)_T$ over the total e range shown while those of the present study although lying within the data band in the low e range also underestimate α_T and $(L/D)_T$ in the high e range, the error increasing uniformly with increasing e.

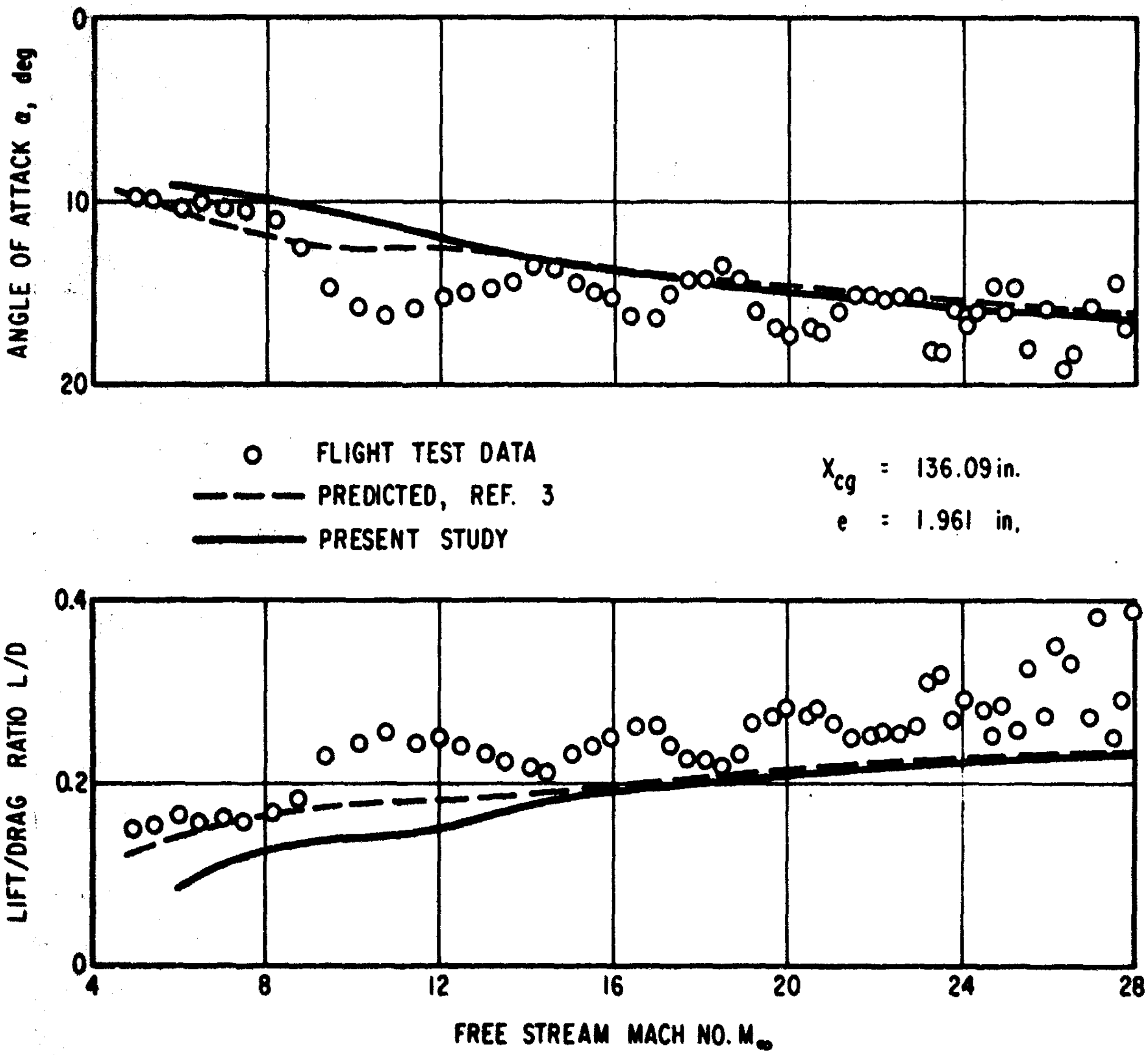

Figure 10a. Angle of Attack and Lift/Drag Ratio GT-2 Re-entry

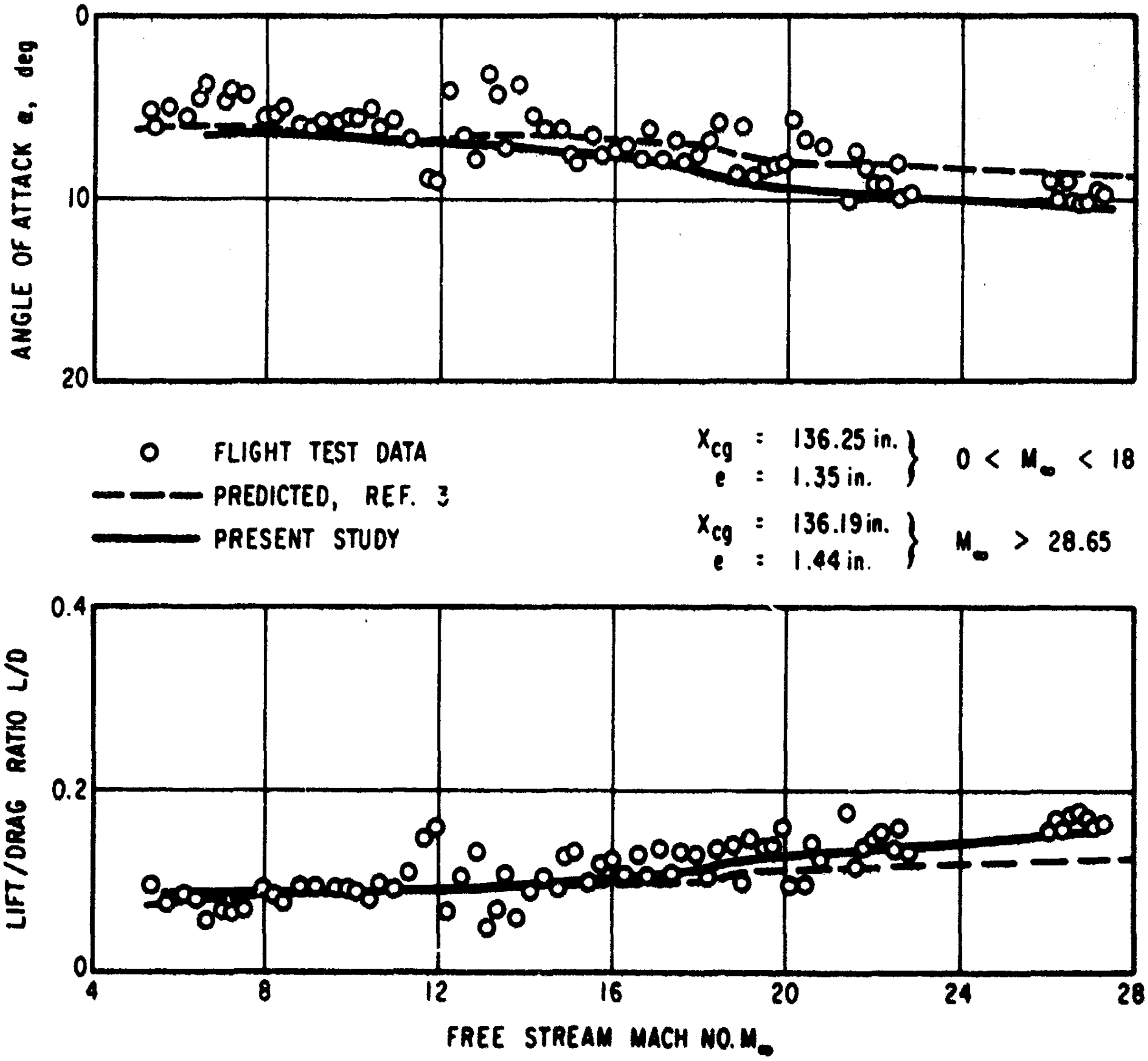

Figure 10b. Angle of Attack and Lift/Drag Ratio GT-3 Re-entry

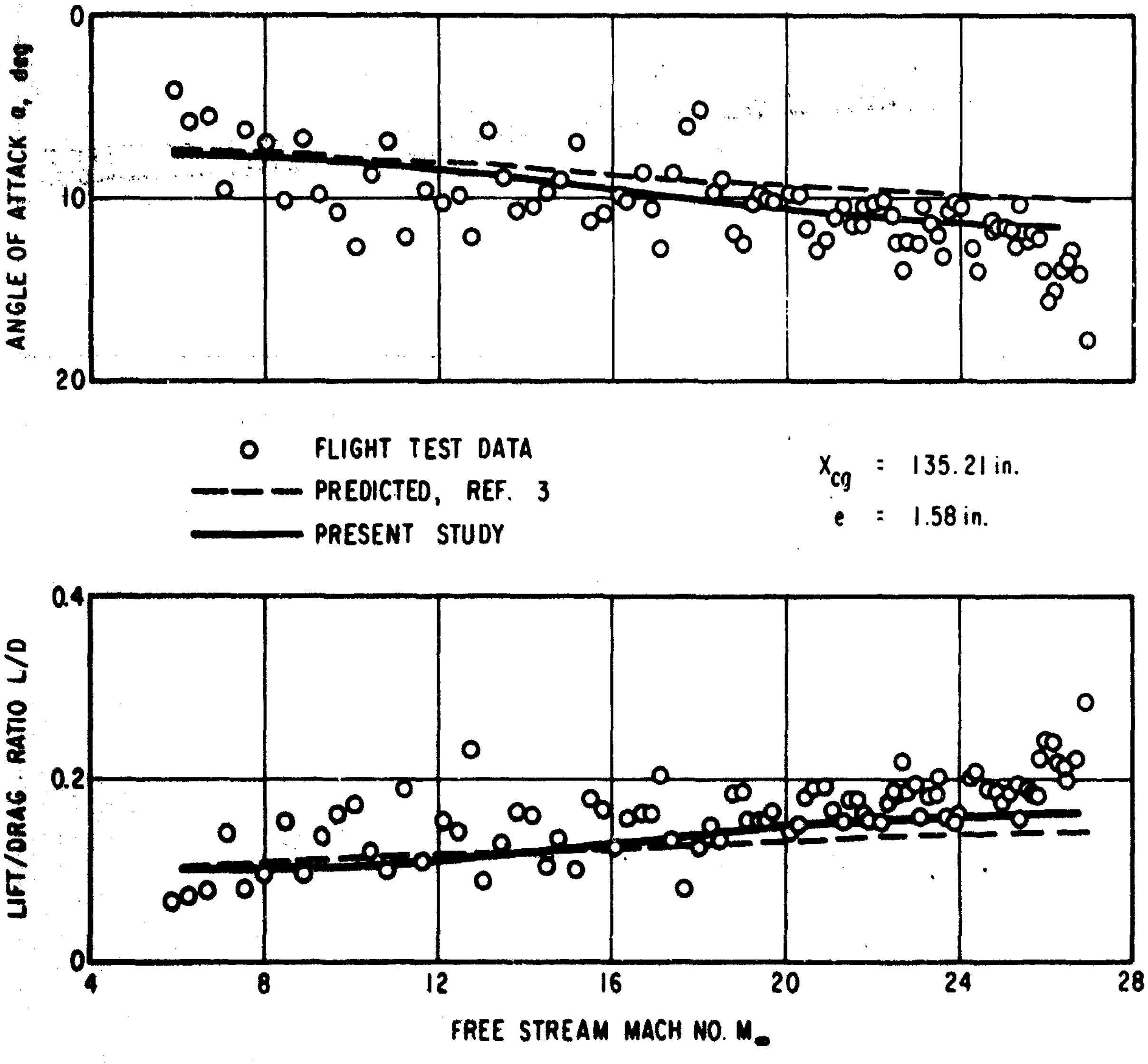

Figure 10c. Angle of Attack and Lift/Drag Ratio GT-4 Re-entry

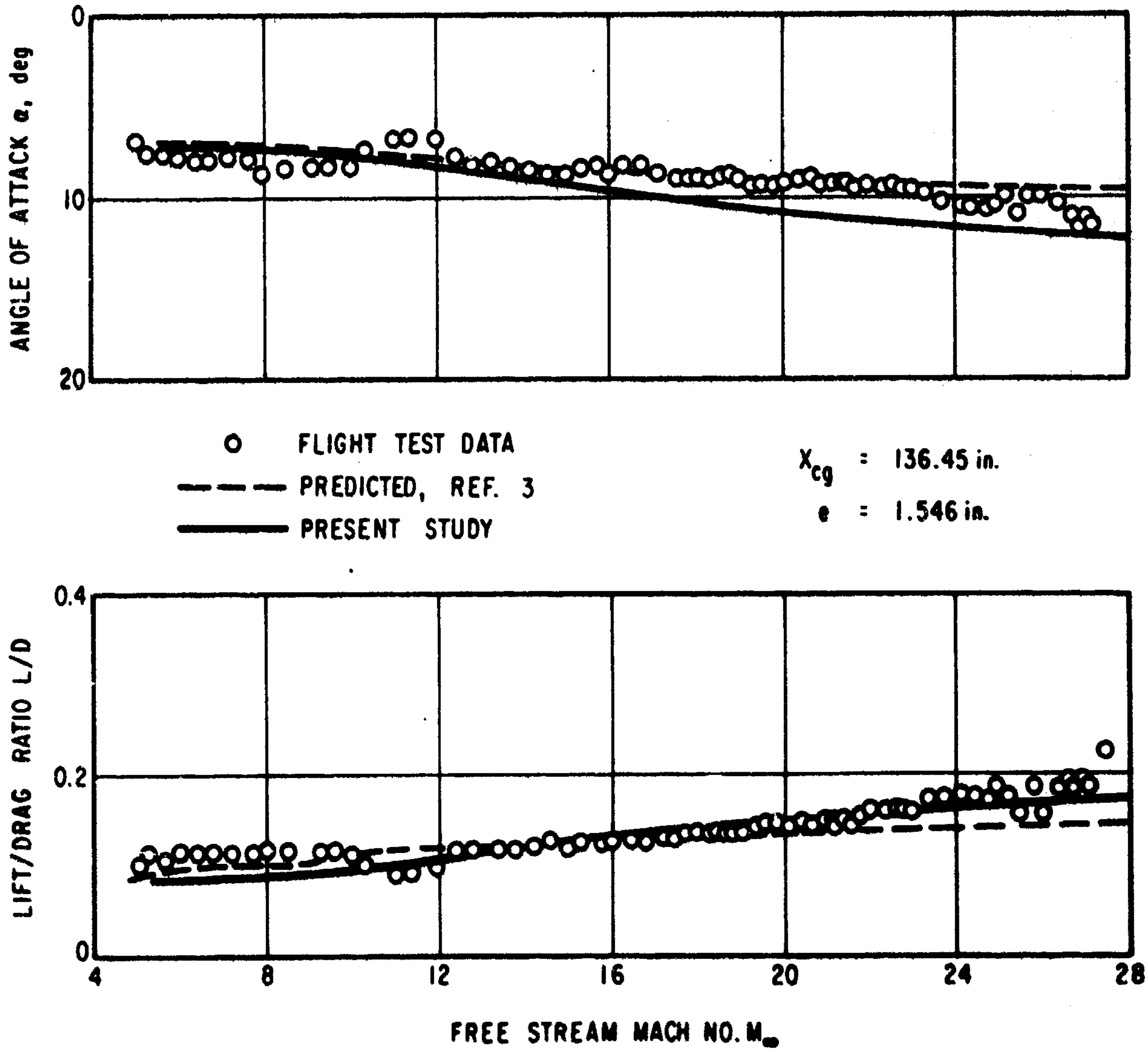

Figure 10d. Angle of Attack and Lift/Drag Ratio GT-5 Re-entry

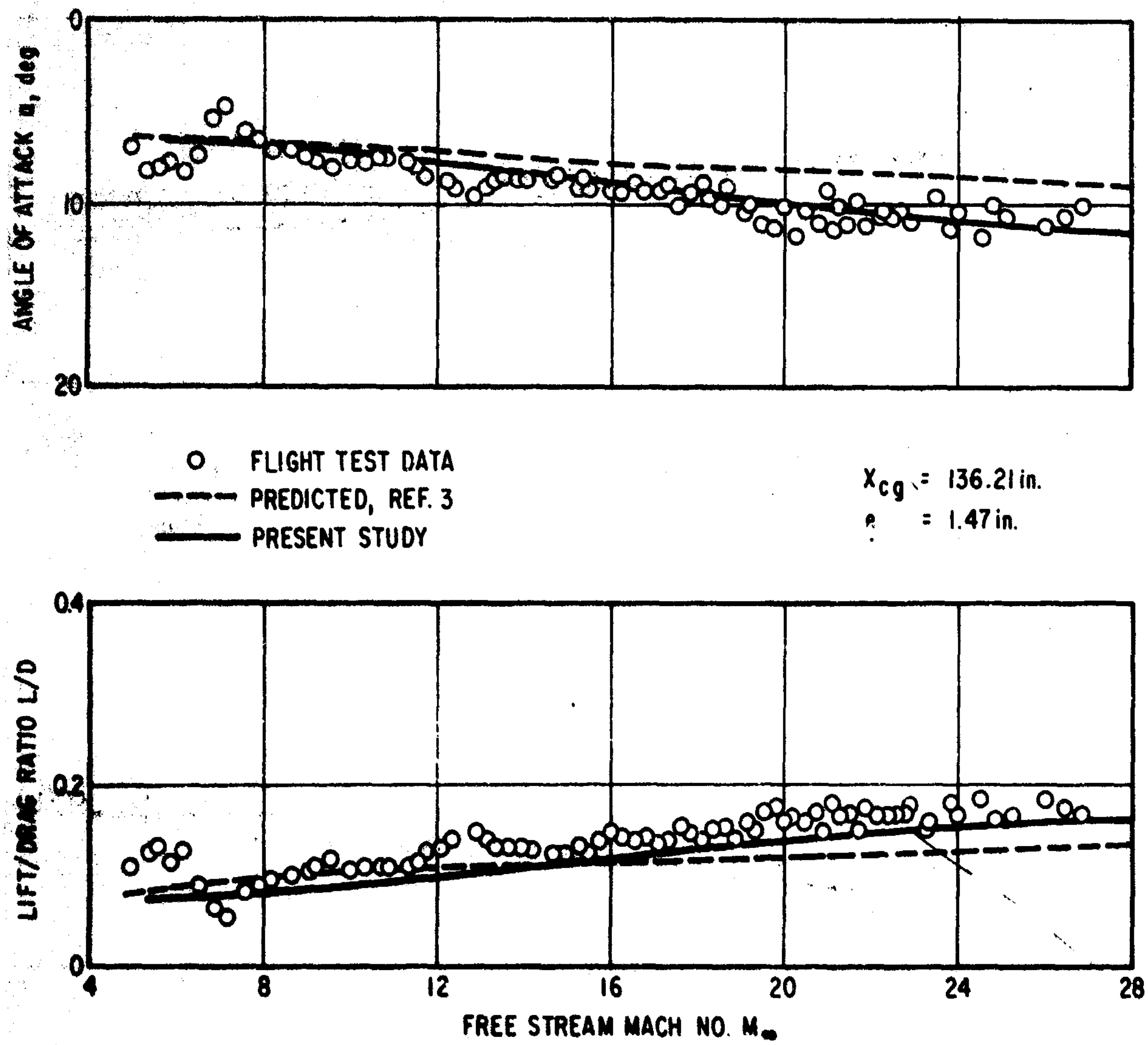

Figure 10e. Angle of Attack and Lift/Drag Ratio GT-8 Re-entry

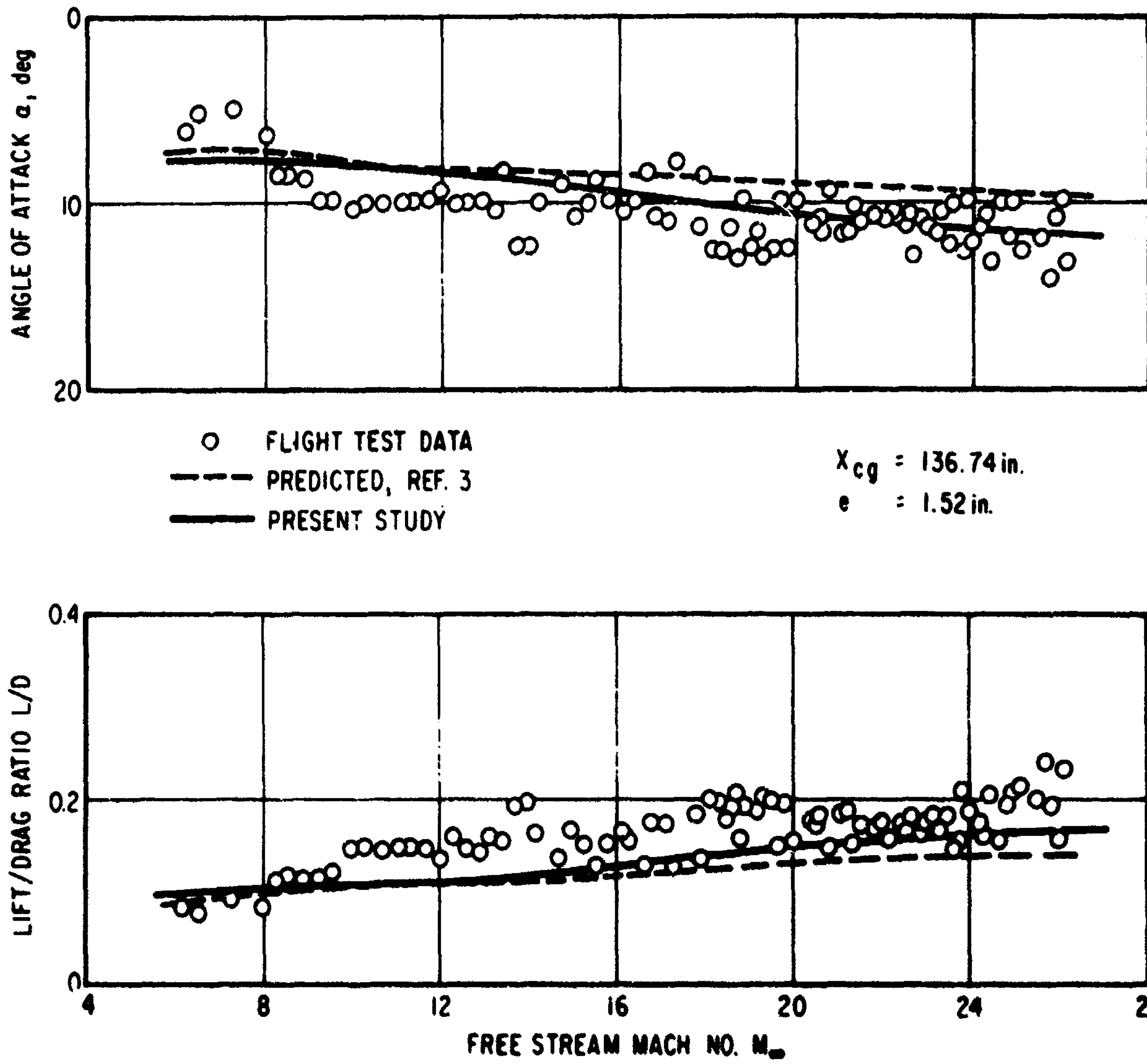

Figure 10f. Angle of Attack and Lift/Drag Ratio GT-10 Re-entry

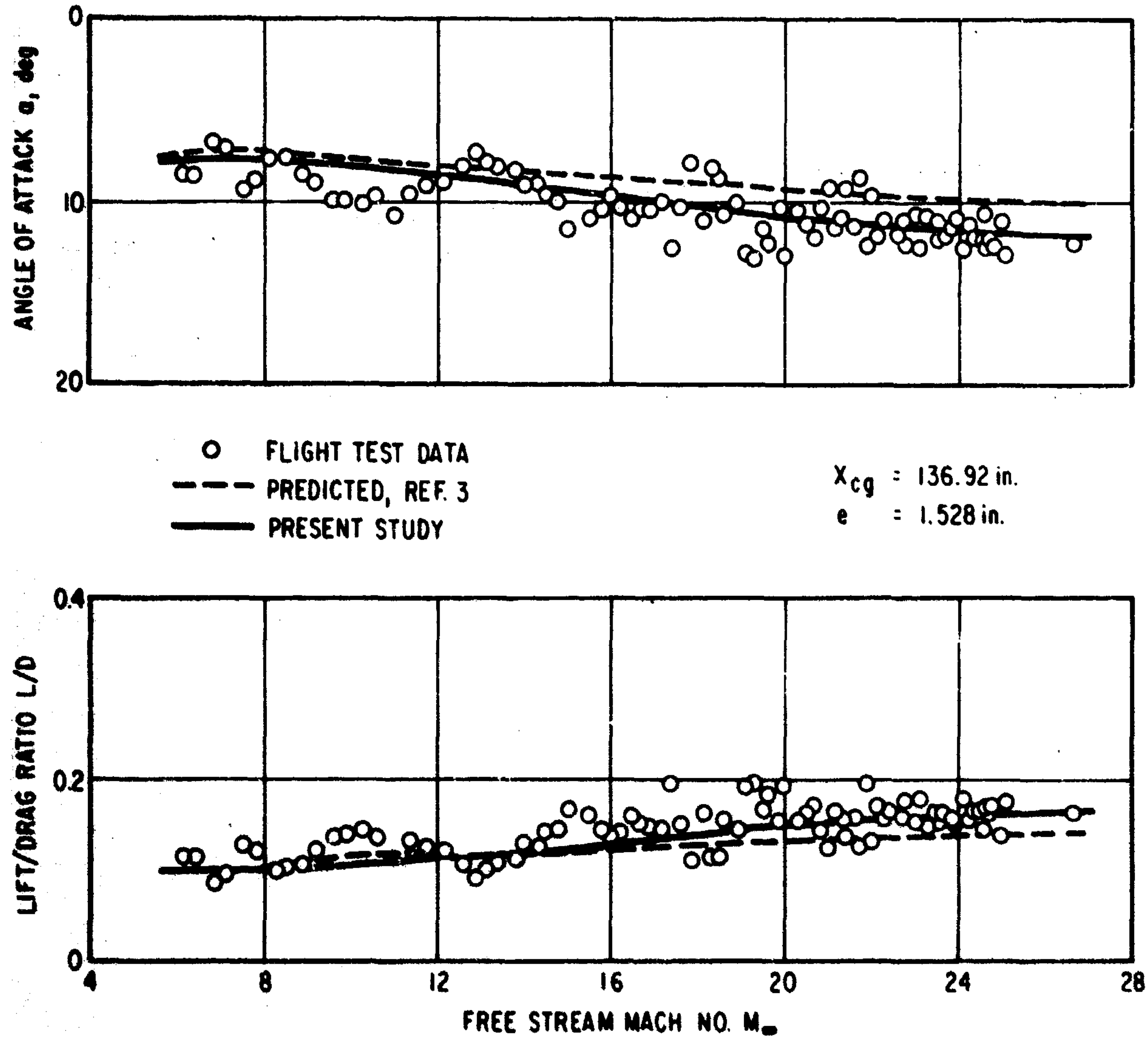

Figure 10g. Angle of Attack and Lift/Drag Ratio GT-11 Re-entry

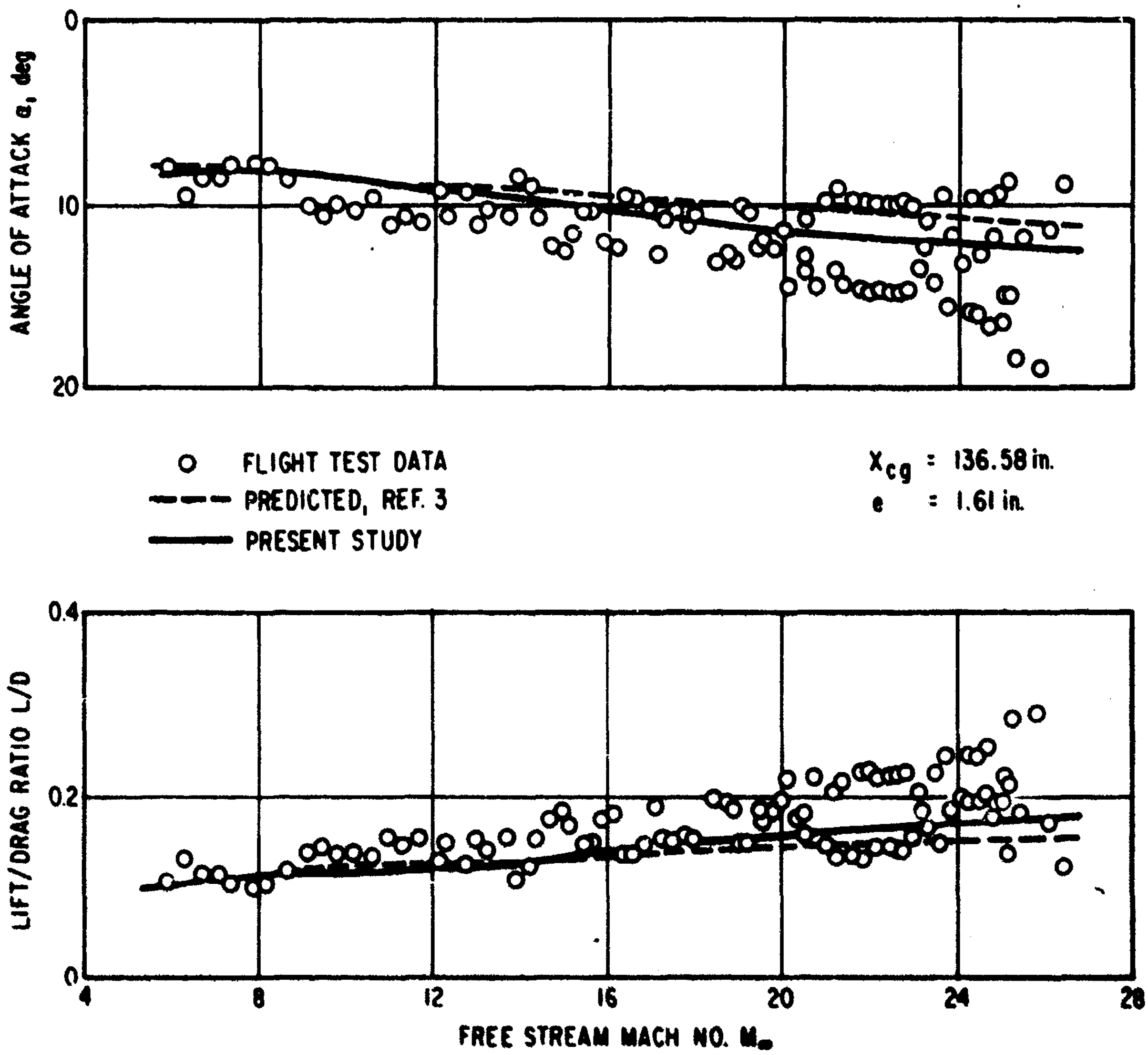

Figure 10h. Angle of Attack and Lift/Drag Ratio GT-12 Re-entry

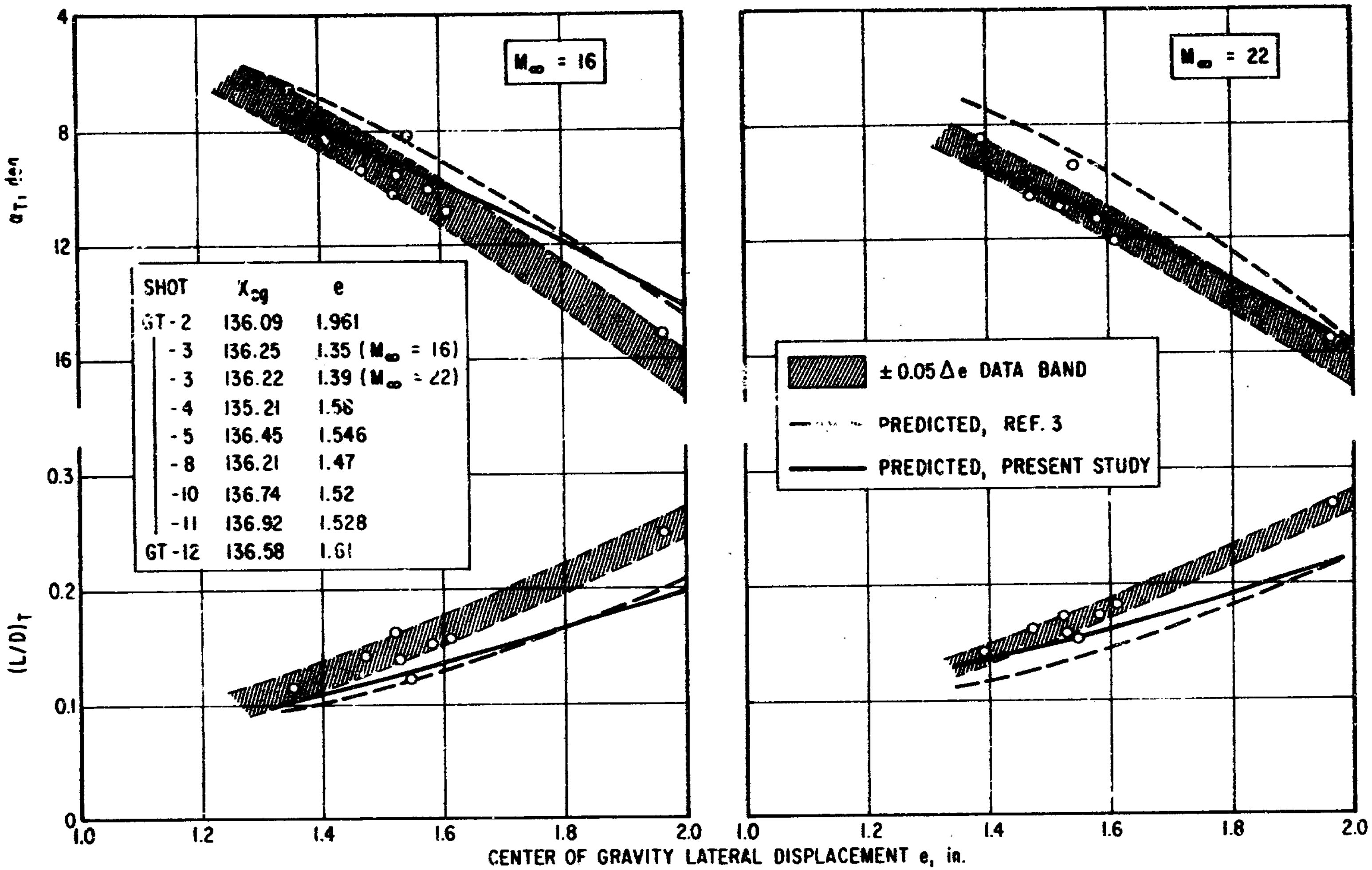

Figure 11. Variation of Trim Characteristics with Lateral CG Displacement

5.2 RE-ENTRY TRAJECTORY IMPACT POINT

Computed re-entry trajectory impact points are compared in Table IV for trajectory simulations using both the Gemini B predicted trim characteristics and those of the present study. In part (a) of Table IV, three design re-entry conditions with zero and full lift are shown. The impact points based on the trim characteristics of the present study always fall uprange of the Gemini B predictions. This behavior is attributed to the higher C_A of the present study for the zero lift cases and a lower $(L/D)_T$ for the full lift trajectories.

A comparison of actual and predicted impact points for the Gemini B HST flight is presented in part (b) of Table IV. The separation conditions used for the trajectory simulation are those reported for the test article in the postflight analysis (Ref. 18). The computed impact point based on the Gemini B predicted trim characteristics is 28 n mi uprange and that based on the present study is 84 n mi uprange of the actual HST impact point. These differences are consistent with the relative values of $(L/D)_T$ shown in Figure 11 for the postflight estimated e of 2.09 in.

5.3 AXIAL LOAD FACTOR

The predicted values of axial load factor for the GT-2 and GT-5, Ref. 19, which are based on the aerodynamic characteristics of Ref. 3 have been modified to reflect the larger predicted C_A of the present study and both are shown in Figure 12 with measured flight data. It appears from these results that tailoring C_A to the operational boundary Cp_{max} of Figure 4 provides a more satisfactory correlation of estimate with flight data.

Table IV. Trajectory Simulation

(a) GBQ Design Conditions $X_{cg} = 135.20$ $e = 1.940$

Apogee Altitude	Apogee Velocity	γ_{Rel}	Lift Condition	Range: Gemini B Predicted	Range: Present Predicted	Δ Range
575,000	20,000	-5.76 deg	Zero	382.6	381.6	-1.0
			Full	427.5	424.3	-3.2
606,000	22,000	-4.60 deg	Zero	484.6	483.1	-1.5
			Full	563.3	557.4	-5.9
635,000	24,000	-2.97	Zero	736.7	733.9	-2.8
			Full	908.2	897.0	-11.2

(b) Gemini B HST $X_{cg} = 135.19$ $e = 2.09$

Flight	V_{Rel}	γ_{Rel}	Lift Condition	Range (n mi)	Error (n mi)
Actual	24,575	-1.80	Full	1911.	---
Gemini B Predicted				1882.79	-28
Present Predicted				1827.31	-84

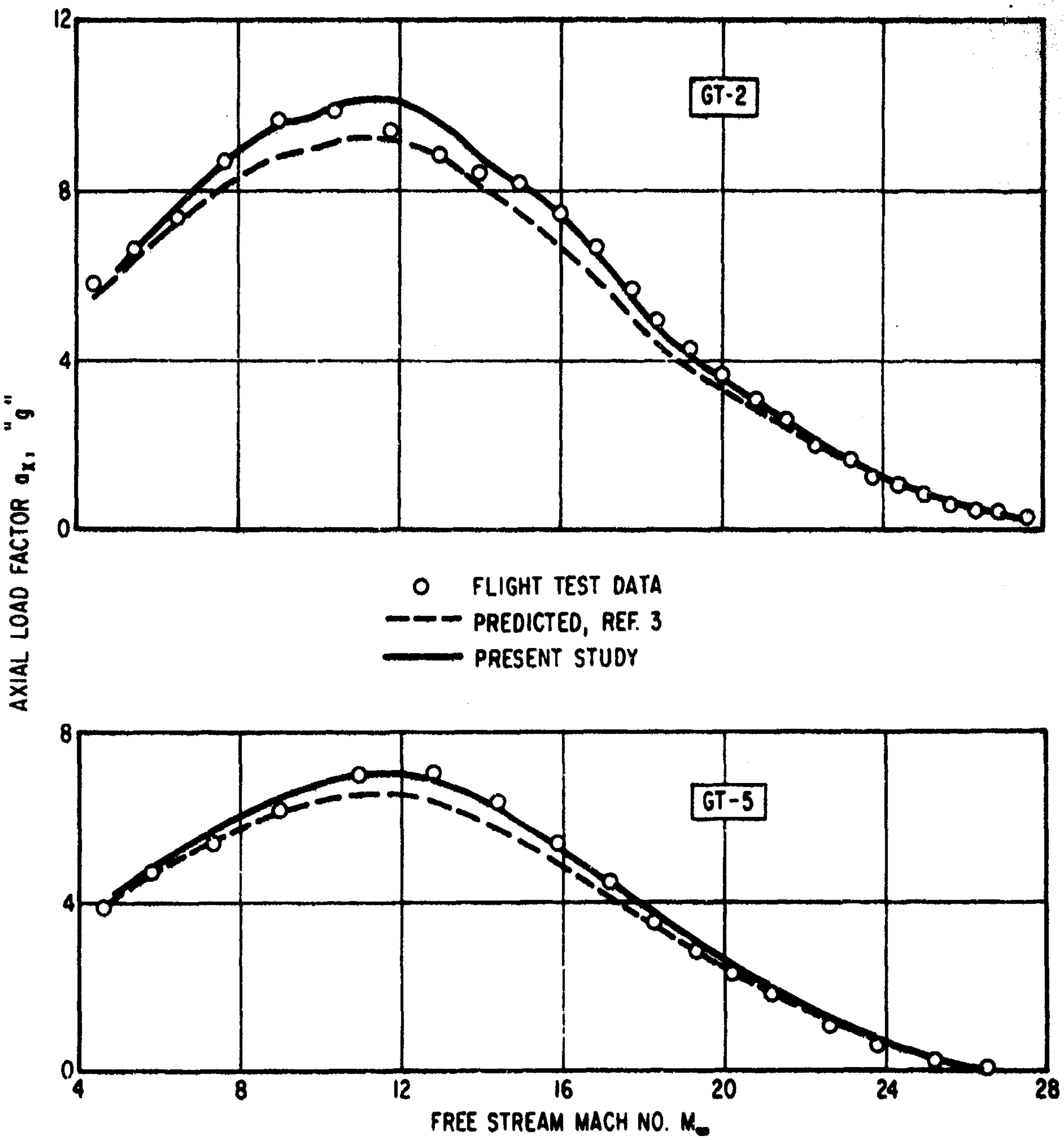

Figure 12. Axial Load Factor

6. DISCUSSION OF RESULTS

A set of hypersonic aerodynamic characteristics has been obtained for the Gemini re-entry module based on an examination of the flow phenomena involved and the application of a least squares curve fit technique to the available wind tunnel test data. Comparison of flight data with predictions based on these characteristics shows varying degrees of correlation. It is considered that the aerodynamic characteristics of the present study are a good representation of the existing wind tunnel test data and it is unlikely that any additional wind tunnel tests will alter these results to a significant degree. If the flight test data is considered valid, then clearly a fundamental difference exists between the aerodynamic characteristics of the small-scale Gemini test models and the full-scale flight articles.

It has been shown that a serious deficiency in H_o simulation may result in C_N and $C_{m_{ref}}$ test data of questionable validity. To identify further the simulation deficiency as the probable source of error between predicted and flight performance, the sensitivity of the trim characteristics to small variations in the aerodynamic coefficients has been examined using the GT-2 c.g. position, M_∞ of 22, and the aerodynamic characteristics and 99.7 percent confidence intervals of the present study. The results are summarized in Table V and clearly show the large sensitivity of α_T and $(L/D)_T$ to small variations in $C_{m_{ref}}$ as well as the moderate sensitivity of α_T to variations in C_N.

Differences in test and flight C_N and $C_{m_{ref}}$ may result from sting interference effects as well as lack of ablation and total enthalpy simulation. All those possible error sources manifest themselves in an altered afterbody pressure distribution and would have an increasing trend with higher α as shown in Figure 6. This is of particular interest since the observed divergence of flight and predicted characteristics with increasing e, Figure 11, is in reality a divergence with increasing α.

Table V. Trim Characteristics Sensitivity on GT-2 at M = 22

α_T = 15.36 deg $(L/D)_T$ = 0.217				
Coefficient	Nominal Value	99.7 Percent Confidence Interval	$\Delta\alpha_T$, deg	$\Delta(L/D)_T$
C_A	1.657	± 0.026	± 0.32	± 0.0046
C_N	0.0899	± 0.011	± 0.63	± 0.0022
$C_{m_{ref}}$	0.0454	± 0.0034	± 1.94	± 0.029

It is, therefore, considered that the set of wind tunnel based aerodynamic characteristics and the set of flight measured trim characteristics are each self-consistent but that there exist small variations between these two sets which are due primarily to differences in flight and wind tunnel values of $C_{N_{AB}}$ and $C_{m_{refAB}}$. Furthermore, since these differences are due to basic limitations in wind tunnel capability, they can only be resolved by application of correction factors obtained from flight test.

7. CONCLUSIONS

A curve fit of the appropriate wind tunnel test data and a correlation of estimated performance with flight values have been performed for the Gemini re-entry module resulting in the following conclusions:

a. The afterbody contribution to C_N and $C_{m_{ref}}$ is not negligible and is Reynolds number dependent.

b. The hypersonic aerodynamic characteristics of the Gemini re-entry module based on wind tunnel test data and for $|\alpha| < 30$ deg are adequately described for continuum flow by equations of the form

$$C_A = C_{P_{max}} [A_1 + A_2 \sin^2\alpha]$$

$$C_N = C_{P_{max}} [B_1 + B_2 \sin\alpha\cos\alpha + B_3 \sin(10\alpha) + B_4 \sin^3\alpha]$$

$$C_{m_{ref}} = C_{P_{max}} [C_1 + C_2 \sin\alpha\cos\alpha + C_3 \sin(10\alpha) + C_4 \sin^3\alpha]$$

where the A_i, B_i, C_i are rational functions of the form $A_i = (a_1 + a_2 M_\infty^{-1} + a_3 M_\infty)$, where the a_i are constants and $C_{P_{max}}$ is based on the Gemini re-entry trajectory operational v-h envelope.

c. The sets of wind tunnel and flight data are each self-consistent. Lack of close correlation of these sets is attributed almost wholly to differences between test and flight values of $C_{N_{AB}}$ and $C_{m_{ref_{AB}}}$.

d. The inability of presently operational ground test facilities to simulate flight values of total enthalpy preclude further wind tunnel testing as a method of refining the existing set of Gemini hypersonic aerodynamic characteristics. Refinements may be achieved through acquisition of new and more intensive examination of existing flight data.

8. RECOMMENDATIONS

a. It is recommended that the sensitivity of Gemini B system requirements to tolerances in predicted aerodynamic characteristics be established through appropriate systems studies.

b. If the results of (a) indicate that further refinement of predicted characteristics is warranted, it is recommended that the existing NASA flight test data be re-examined and if found adequate in extent and accuracy, that it be used as a basis for development of a set of correction factors to be applied to the estimated aerodynamic characteristics of the present analysis. This will require a review of present flight test data reduction techniques and development of new ones if found inadequate.

c. It is further recommended that in the planning of future test flights of the Gemini B series, greater consideration be given to the acquisition of data required for the definition of the vehicle aerodynamic coefficients as well as to α and L/D.

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 0.5

ALPHA	CNREF	CN	CA
30	1.58000000E-01	1.40000000E-01	1.04000000E+00
29	1.54000000E-01	1.25000000E-01	1.04500000E+00
28	1.50000000E-01	1.10000000E-01	1.07500000E+00
27	1.46000000E-01	9.50000000E-02	1.09000000E+00
26	1.41000000E-01	8.00000000E-02	1.10500000E+00
25	1.34000000E-01	7.00000000E-02	1.11500000E+00
24	1.28000000E-01	5.50000000E-02	1.12500000E+00
23	1.22000000E-01	4.50000000E-02	1.13500000E+00
22	1.16000000E-01	3.50000000E-02	1.14500000E+00
21	1.08000000E-01	2.50000000E-02	1.15000000E+00
20	1.02000000E-01	1.00000000E-02	1.15500000E+00
19	9.60000000E-02	0.	1.16500000E+00
18	8.80000000E-02	-1.00000000E-02	1.17000000E+00
17	8.20000000E-02	-2.00000000E-02	1.17500000E+00
16	7.50000000E-02	-3.00000000E-02	1.18000000E+00
15	6.70000000E-02	-3.50000000E-02	1.18500000E+00
14	6.20000000E-02	-4.00000000E-02	1.18700000E+00
13	5.60000000E-02	-5.00000000E-02	1.19000000E+00
12	4.90000000E-02	-5.50000000E-02	1.19000000E+00
11	4.30000000E-02	-6.00000000E-02	1.19000000E+00
10	3.80000000E-02	-6.50000000E-02	1.18700000E+00
9	3.30000000E-02	-6.50000000E-02	1.18500000E+00
8	2.80000000E-02	-6.50000000E-02	1.18300000E+00
7	2.40000000E-02	-6.50000000E-02	1.18000000E+00
6	2.00000000E-02	-6.00000000E-02	1.17500000E+00
5	1.70000000E-02	-5.50000000E-02	1.17000000E+00
4	1.30000000E-02	-5.00000000E-02	1.16500000E+00
3	1.00000000E-02	-4.00000000E-02	1.15500000E+00
2	7.00000000E-03	-3.00000000E-02	1.15000000E+00
1	4.00000000E-03	-1.50000000E-02	1.14500000E+00
0	0.	0.	1.14500000E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 0.6

ALPHA	CNREF	CN	CA
30	1.32000000E-01	1.35000000E-01	1.13000000E+00
29	1.24000000E-01	1.20000000E-01	1.14500000E+00
28	1.18000000E-01	1.10000000E-01	1.15500000E+00
27	1.11000000E-01	9.50000000E-02	1.17000000E+00
26	1.02000000E-01	8.50000000E-02	1.18000000E+00
25	9.70000000E-02	7.50000000E-02	1.19500000E+00
24	9.00000000E-02	7.00000000E-02	1.20500000E+00
23	8.30000000E-02	6.50000000E-02	1.21500000E+00
22	7.70000000E-02	5.50000000E-02	1.22500000E+00
21	7.00000000E-02	5.00000000E-02	1.23000000E+00
20	6.30000000E-02	4.00000000E-02	1.24000000E+00
19	5.70000000E-02	3.50000000E-02	1.24500000E+00
18	5.20000000E-02	3.00000000E-02	1.25000000E+00
17	4.60000000E-02	2.50000000E-02	1.25500000E+00
16	4.20000000E-02	1.50000000E-02	1.26000000E+00
15	3.70000000E-02	1.00000000E-02	1.26500000E+00
14	3.30000000E-02	5.00000000E-03	1.27000000E+00
13	3.00000000E-02	0.	1.27000000E+00
12	2.80000000E-02	-5.00000000E-03	1.27000000E+00
11	2.70000000E-02	-1.00000000E-02	1.27000000E+00
10	2.60000000E-02	-1.50000000E-02	1.27000000E+00
9	2.40000000E-02	-2.00000000E-02	1.27000000E+00
8	2.20000000E-02	-2.00000000E-02	1.26500000E+00
7	1.90000000E-02	-2.50000000E-02	1.26500000E+00
6	1.80000000E-02	-2.50000000E-02	1.26000000E+00
5	1.60000000E-02	-3.00000000E-02	1.25500000E+00
4	1.30000000E-02	-3.00000000E-02	1.25000000E+00
3	1.10000000E-02	-2.50000000E-02	1.24000000E+00
2	8.00000000E-03	-2.00000000E-02	1.23500000E+00
1	4.00000000E-03	-1.00000000E-02	1.23000000E+00
0	0.	-0.	1.22500000E+00

APPENDIX (Sheet 2 of 11)

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 0.93

ALPHA	CMREF	CN	CA
30	1.40000000E-01	1.55000000E-01	1.19000000E+00
29	1.33000000E-01	1.40000000E-01	1.20500000E+00
28	1.22000000E-01	1.25000000E-01	1.22000000E+00
27	1.10000000E-01	1.10000000E-01	1.23500000E+00
26	9.80000000E-02	1.00000000E-01	1.24500000E+00
25	8.90000000E-02	8.50000000E-02	1.25500000E+00
24	8.00000000E-02	7.00000000E-02	1.26500000E+00
23	7.20000000E-02	6.50000000E-02	1.27500000E+00
22	6.60000000E-02	5.50000000E-02	1.28000000E+00
21	6.00000000E-02	5.00000000E-02	1.29500000E+00
20	5.30000000E-02	4.00000000E-02	1.29500000E+00
19	4.90000000E-02	3.50000000E-02	1.29500000E+00
18	4.50000000E-02	3.00000000E-02	1.30000000E+00
17	4.10000000E-02	2.50000000E-02	1.30000000E+00
16	3.70000000E-02	2.00000000E-02	1.30500000E+00
15	3.30000000E-02	1.50000000E-02	1.30500000E+00
14	3.10000000E-02	1.00000000E-02	1.30500000E+00
13	2.80000000E-02	5.00000000E-03	1.30500000E+00
12	2.60000000E-02	0.	1.30500000E+00
11	2.30000000E-02	-5.00000000E-03	1.30500000E+00
10	2.10000000E-02	-1.00000000E-02	1.30000000E+00
9	1.90000000E-02	-1.00000000E-02	1.30000000E+00
8	1.80000000E-02	-1.50000000E-02	1.29500000E+00
7	1.70000000E-02	-1.50000000E-02	1.29500000E+00
6	1.50000000E-02	-2.00000000E-02	1.29000000E+00
5	1.40000000E-02	-2.50000000E-02	1.28500000E+00
4	1.30000000E-02	-3.00000000E-02	1.28000000E+00
3	1.20000000E-02	-3.50000000E-02	1.27500000E+00
2	1.00000000E-02	-3.20000000E-02	1.27000000E+00
1	6.00000000E-03	-2.10000000E-02	1.26000000E+00
0	0.	0.	1.25500000E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 1.13

ALPHA	CMREF	CN	CA
30	1.73000000E-01	2.15000000E-01	1.25500000E+00
29	1.58000000E-01	1.90000000E-01	1.26500000E+00
28	1.42000000E-01	1.65000000E-01	1.28000000E+00
27	1.26000000E-01	1.45000000E-01	1.29000000E+00
26	1.10000000E-01	1.30000000E-01	1.30000000E+00
25	9.80000000E-02	1.10000000E-01	1.31000000E+00
24	8.70000000E-02	9.40000000E-02	1.31500000E+00
23	7.70000000E-02	8.00000000E-02	1.32500000E+00
22	6.80000000E-02	6.00000000E-02	1.33500000E+00
21	6.00000000E-02	5.50000000E-02	1.34000000E+00
20	5.30000000E-02	5.00000000E-02	1.34500000E+00
19	4.70000000E-02	4.00000000E-02	1.34000000E+00
18	4.30000000E-02	3.50000000E-02	1.35000000E+00
17	3.80000000E-02	3.00000000E-02	1.36000000E+00
16	3.30000000E-02	2.50000000E-02	1.36000000E+00
15	2.90000000E-02	2.00000000E-02	1.36500000E+00
14	2.60000000E-02	2.00000000E-02	1.36500000E+00
13	2.30000000E-02	1.50000000E-02	1.37000000E+00
12	2.20000000E-02	1.50000000E-02	1.36500000E+00
11	2.00000000E-02	1.50000000E-02	1.36000000E+00
10	1.80000000E-02	1.50000000E-02	1.36000000E+00
9	1.60000000E-02	1.00000000E-02	1.34000000E+00
8	1.50000000E-02	1.00000000E-02	1.34000000E+00
7	1.40000000E-02	5.00000000E-03	1.34000000E+00
6	1.30000000E-02	0.	1.35500000E+00
5	1.20000000E-02	-5.00000000E-03	1.35000000E+00
4	1.10000000E-02	-1.00000000E-02	1.34500000E+00
3	1.00000000E-02	-2.00000000E-02	1.34000000E+00
2	9.00000000E-03	-2.30000000E-02	1.33000000E+00
1	6.00000000E-03	-1.90000000E-02	1.32000000E+00
0	0.	0.	1.31000000E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 1.6

ALPHA	CHREF	CN	CA
30	1.81000000E-01	3.90000000E-01	1.39000000E+00
29	1.74000000E-01	3.65000000E-01	1.41000000E+00
28	1.68000000E-01	3.40000000E-01	1.42000000E+00
27	1.58000000E-01	3.15000000E-01	1.43500000E+00
26	1.48000000E-01	2.95000000E-01	1.45000000E+00
25	1.40000000E-01	2.70000000E-01	1.46500000E+00
24	1.32000000E-01	2.45000000E-01	1.48000000E+00
23	1.23900000E-01	2.10000000E-01	1.49000000E+00
22	1.16000000E-01	1.95000000E-01	1.50000000E+00
21	1.07000000E-01	1.75000000E-01	1.51500000E+00
20	1.00000000E-01	1.55000000E-01	1.52500000E+00
19	9.20000000E-02	1.40000000E-01	1.53500000E+00
18	8.60000000E-02	1.25000000E-01	1.54000000E+00
17	7.80000000E-02	1.10000000E-01	1.54500000E+00
16	7.20000000E-02	9.50000000E-02	1.55500000E+00
15	6.50000000E-02	8.50000000E-02	1.56500000E+00
14	5.80000000E-02	7.50000000E-02	1.57000000E+00
13	5.30000000E-02	6.50000000E-02	1.57500000E+00
12	4.70000000E-02	5.50000000E-02	1.58000000E+00
11	4.20000000E-02	5.00000000E-02	1.58000000E+00
10	3.70000000E-02	4.50000000E-02	1.58500000E+00
9	3.20000000E-02	3.50000000E-02	1.58500000E+00
8	2.80000000E-02	3.00000000E-02	1.59000000E+00
7	2.40000000E-02	2.50000000E-02	1.59000000E+00
6	1.90000000E-02	2.00000000E-02	1.59000000E+00
5	1.60000000E-02	1.50000000E-02	1.59000000E+00
4	1.30000000E-02	1.00000000E-02	1.58500000E+00
3	1.10000000E-02	1.00000000E-02	1.58500000E+00
2	8.00000000E-03	1.00000000E-02	1.58000000E+00
1	4.00000000E-03	8.00000000E-03	1.58000000E+00
0	0.	0.	1.58000000E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 1.98

ALPHA	CHREF	CN	CA
30	1.76000000E-01	3.90000000E-01	1.40000000E+00
29	1.72000000E-01	3.60000000E-01	1.41000000E+00
28	1.67000000E-01	3.45000000E-01	1.43000000E+00
27	1.63000000E-01	3.25000000E-01	1.45000000E+00
26	1.58000000E-01	3.10000000E-01	1.47000000E+00
25	1.55000000E-01	2.90000000E-01	1.48000000E+00
24	1.50000000E-01	2.75000000E-01	1.50000000E+00
23	1.46000000E-01	2.60000000E-01	1.51000000E+00
22	1.42000000E-01	2.45000000E-01	1.53000000E+00
21	1.38000000E-01	2.30000000E-01	1.54000000E+00
20	1.34000000E-01	2.10000000E-01	1.55000000E+00
19	1.30000000E-01	2.00000000E-01	1.56500000E+00
18	1.26000000E-01	1.85000000E-01	1.57000000E+00
17	1.21000000E-01	1.70000000E-01	1.58000000E+00
16	1.14000000E-01	1.55000000E-01	1.59000000E+00
15	1.08000000E-01	1.40000000E-01	1.60000000E+00
14	1.02000000E-01	1.25000000E-01	1.60000000E+00
13	9.30000000E-02	1.15000000E-01	1.60000000E+00
12	8.40000000E-02	9.00000000E-02	1.60000000E+00
11	7.20000000E-02	8.50000000E-02	1.60000000E+00
10	6.10000000E-02	7.50000000E-02	1.60000000E+00
9	4.80000000E-02	6.00000000E-02	1.60000000E+00
8	4.10000000E-02	5.00000000E-02	1.60000000E+00
7	3.40000000E-02	4.00000000E-02	1.60000000E+00
6	2.80000000E-02	3.50000000E-02	1.60000000E+00
5	2.30000000E-02	2.50000000E-02	1.60000000E+00
4	1.90000000E-02	1.50000000E-02	1.60000000E+00
3	1.70000000E-02	1.00000000E-02	1.60000000E+00
2	1.30000000E-02	5.00000000E-03	1.60000000E+00
1	7.00000000E-03	5.00000000E-03	1.60000000E+00
0	0.	0.	1.60000000E+00

APPENDIX (Sheet 4 of 11)

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 2.98

ALPHA	CHREF	CN	CA
30	1.28000000E-01	2.85000000E-01	1.33000000E+00
29	1.23000000E-01	2.70000000E-01	1.35000000E+00
28	1.19000000E-01	2.55000000E-01	1.37000000E+00
27	1.15000000E-01	2.45000000E-01	1.39000000E+00
26	1.12000000E-01	2.35000000E-01	1.41000000E+00
25	1.08000000E-01	2.25000000E-01	1.43000000E+00
24	1.04000000E-01	2.10000000E-01	1.44500000E+00
23	1.01000000E-01	2.00000000E-01	1.46000000E+00
22	9.80000000E-02	1.90000000E-01	1.47500000E+00
21	9.40000000E-02	1.85000000E-01	1.49000000E+00
20	9.10000000E-02	1.75000000E-01	1.50500000E+00
19	8.60000000E-02	1.65000000E-01	1.51500000E+00
18	8.50000000E-02	1.55000000E-01	1.53000000E+00
17	8.20000000E-02	1.45000000E-01	1.54000000E+00
16	7.90000000E-02	1.35000000E-01	1.55000000E+00
15	7.60000000E-02	1.25000000E-01	1.56000000E+00
14	7.30000000E-02	1.20000000E-01	1.57000000E+00
13	6.90000000E-02	1.10000000E-01	1.57500000E+00
12	6.60000000E-02	1.05000000E-01	1.58500000E+00
11	6.20000000E-02	9.50000000E-02	1.59000000E+00
10	5.80000000E-02	9.00000000E-02	1.59500000E+00
9	5.30000000E-02	8.00000000E-02	1.60000000E+00
8	4.80000000E-02	7.00000000E-02	1.60500000E+00
7	4.30000000E-02	6.50000000E-02	1.61000000E+00
6	3.80000000E-02	5.50000000E-02	1.61000000E+00
5	3.20000000E-02	4.50000000E-02	1.61500000E+00
4	2.70000000E-02	4.00000000E-02	1.61500000E+00
3	2.00000000E-02	3.00000000E-02	1.61500000E+00
2	1.30000000E-02	2.00000000E-02	1.61500000E+00
1	7.00000000E-03	1.50000000E-02	1.61500000E+00
0	0.	0.	1.61500000E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 4.86

ALPHA	CHREF	CN	CA
0	0.	0.	1.61530000E+00
1	8.00000000E-03	2.00000000E-02	1.61500000E+00
2	1.30000000E-02	2.50000000E-02	1.61440000E+00
3	1.80000000E-02	3.00000000E-02	1.61380000E+00
4	2.20000000E-02	4.00000000E-02	1.61200000E+00
5	2.70000000E-02	4.50000000E-02	1.61000000E+00
6	3.00000000E-02	5.00000000E-02	1.60720000E+00
7	3.30000000E-02	5.50000000E-02	1.60400000E+00
8	3.60000000E-02	6.00000000E-02	1.60000000E+00
9	4.00000000E-02	6.50000000E-02	1.59580000E+00
10	4.30000000E-02	7.00000000E-02	1.59000000E+00
11	4.50000000E-02	7.50000000E-02	1.58390000E+00
12	4.80000000E-02	8.00000000E-02	1.57620000E+00
13	5.00000000E-02	8.50000000E-02	1.56800000E+00
14	5.30000000E-02	9.00000000E-02	1.55820000E+00
15	5.50000000E-02	9.50000000E-02	1.54800000E+00
16	5.70000000E-02	1.00000000E-01	1.53610000E+00
17	5.90000000E-02	1.05000000E-01	1.52350000E+00
18	6.20000000E-02	1.10000000E-01	1.50950000E+00
19	6.50000000E-02	1.15000000E-01	1.49530000E+00
20	6.90000000E-02	1.20000000E-01	1.48000000E+00
21	7.00000000E-02	1.30000000E-01	1.46420000E+00
22	7.30000000E-02	1.35000000E-01	1.44750000E+00
23	7.50000000E-02	1.40000000E-01	1.42900000E+00
24	7.80000000E-02	1.50000000E-01	1.41120000E+00
25	8.20000000E-02	1.55000000E-01	1.39200000E+00
26	8.50000000E-02	1.65000000E-01	1.37200000E+00
27	8.80000000E-02	1.75000000E-01	1.35200000E+00
28	9.30000000E-02	1.85000000E-01	1.33000000E+00
29	9.70000000E-02	1.95000000E-01	1.31000000E+00
30	1.02000000E-01	2.10000000E-01	1.28900000E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 7

ALPHA	CMREF	CN	CA
0	1.00000000E-03	-3.20000000E-03	1.62600000E+00
1	6.60000000E-03	4.50000000E-03	1.62580000E+00
2	1.11000000E-02	1.22000000E-02	1.62450000E+00
3	1.59000000E-02	1.99000000E-02	1.62300000E+00
4	2.01000000E-02	2.70000000E-02	1.62150000E+00
5	2.45000000E-02	3.46000000E-02	1.61850000E+00
6	2.80000000E-02	4.22000000E-02	1.61580000E+00
7	3.14000000E-02	4.90000000E-02	1.61200000E+00
8	3.45000000E-02	5.50000000E-02	1.60800000E+00
9	3.74000000E-02	6.10000000E-02	1.60230000E+00
10	4.01000000E-02	6.65000000E-02	1.59680000E+00
11	4.26000000E-02	7.20000000E-02	1.59000000E+00
12	4.50000000E-02	7.70000000E-02	1.58220000E+00
13	4.70000000E-02	8.20000000E-02	1.57400000E+00
14	4.90000000E-02	8.75000000E-02	1.56430000E+00
15	5.09000000E-02	9.20000000E-02	1.55380000E+00
16	5.26000000E-02	9.68000000E-02	1.54250000E+00
17	5.48000000E-02	1.02000000E-01	1.53020000E+00
18	5.69000000E-02	1.07200000E-01	1.51700000E+00
19	5.90000000E-02	1.12200000E-01	1.50300000E+00
20	6.18000000E-02	1.18200000E-01	1.48820000E+00
21	6.40000000E-02	1.24000000E-01	1.47280000E+00
22	6.69000000E-02	1.30000000E-01	1.45670000E+00
23	6.98000000E-02	1.37200000E-01	1.43980000E+00
24	7.29000000E-02	1.44500000E-01	1.42180000E+00
25	7.60000000E-02	1.51800000E-01	1.40300000E+00
26	7.94000000E-02	1.60000000E-01	1.38370000E+00
27	8.30000000E-02	1.68500000E-01	1.36370000E+00
28	8.69000000E-02	1.77800000E-01	1.34250000E+00
29	9.10000000E-02	1.87000000E-01	1.32150000E+00
30	9.50000000E-02	1.96800000E-01	1.30000000E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 10

ALPHA	CMREF	CN	CA
0	3.30000000E-03	-1.05000000E-02	1.66610000E+00
1	8.20000000E-03	-1.80000000E-03	1.66580000E+00
2	1.28000000E-02	7.90000000E-03	1.66460000E+00
3	1.69000000E-02	1.62000000E-02	1.66260000E+00
4	2.06000000E-02	2.50000000E-02	1.65990000E+00
5	2.44000000E-02	3.30000000E-02	[illegible]
6	2.80000000E-02	4.15000000E-02	1.65220000E+00
7	3.13000000E-02	4.90000000E-02	1.64720000E+00
8	3.41000000E-02	5.50000000E-02	1.64140000E+00
9	3.70000000E-02	6.23000000E-02	1.63490000E+00
10	3.98000000E-02	[illegible]	[illegible]
11	4.20000000E-02	7.45000000E-02	1.61970000E+00
12	4.45000000E-02	7.95000000E-02	1.61100000E+00
13	4.63000000E-02	8.40000000E-02	1.60190000E+00
14	4.81000000E-02	9.00000000E-02	1.59140000E+00
15	[illegible]	9.47000000E-02	[illegible]
16	5.19000000E-02	9.92000000E-02	1.56910000E+00
17	5.39000000E-02	1.04800000E-01	1.55760000E+00
18	5.59000000E-02	1.10000000E-01	1.54420000E+00
19	5.79000000E-02	1.15000000E-01	1.53000000E+00
20	6.00000000E-02	1.20500000E-01	[illegible]
21	6.20000000E-02	1.26000000E-01	1.50220000E+00
22	6.42000000E-02	1.32000000E-01	1.48700000E+00
23	6.69000000E-02	1.39000000E-01	1.47120000E+00
24	6.96000000E-02	1.46000000E-01	1.45440000E+00
25	7.23000000E-02	[illegible]	1.43810000E+00
26	7.54000000E-02	1.62000000E-01	1.42000000E+00
27	7.90000000E-02	1.70200000E-01	1.40300000E+00
28	8.28600000E-02	1.79000000E-01	1.38470000E+00
29	8.67000000E-02	1.88200000E-01	1.36660000E+00
30	9.18000000E-02	1.98000000E-01	1.34600000E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 12

ALPHA	CHREF	CN	CA
0	5.80000000E-03	-1.15000000E-02	1.68810000E+00
1	9.80000000E-03	-2.50000000E-03	1.68770000E+00
2	1.37000000E-02	7.00000000E-03	1.68650000E+00
3	1.73000000E-02	1.58000000E-02	1.68450000E+00
4	2.06000000E-02	2.42000000E-02	1.68170000E+00
5	2.46000000E-02	3.25000000E-02	1.67820000E+00
6	2.75000000E-02	4.05000000E-02	1.67380000E+00
7	3.04000000E-02	4.85000000E-02	1.66870000E+00
8	3.33000000E-02	5.50000000E-02	1.66280000E+00
9	3.60000000E-02	6.20000000E-02	1.65620000E+00
10	3.88000000E-02	6.82000000E-02	1.64880000E+00
11	4.10000000E-02	7.40000000E-02	1.64060000E+00
12	4.35000000E-02	7.95000000E-02	1.63170000E+00
13	4.54000000E-02	8.48000000E-02	1.62210000E+00
14	4.74000000E-02	9.00000000E-02	1.61180000E+00
15	4.92000000E-02	9.45000000E-02	1.60080000E+00
16	5.09000000E-02	9.92000000E-02	1.58910000E+00
17	5.26000000E-02	1.04200000E-01	1.57670000E+00
18	5.42000000E-02	1.09500000E-01	1.56360000E+00
19	5.61000000E-02	1.14200000E-01	1.55000000E+00
20	5.80000000E-02	1.20000000E-01	1.53560000E+00
21	6.02000000E-02	1.25800000E-01	1.52070000E+00
22	6.27000000E-02	1.31500000E-01	1.50520000E+00
23	6.49000000E-02	1.38000000E-01	1.48910000E+00
24	6.75000000E-02	1.45000000E-01	1.47250000E+00
25	7.02000000E-02	1.52200000E-01	1.45530000E+00
26	7.35000000E-02	1.60500000E-01	1.43770000E+00
27	7.70000000E-02	1.69000000E-01	1.41950000E+00
28	8.06000000E-02	1.79000000E-01	1.40090000E+00
29	8.44000000E-02	1.88000000E-01	1.38180000E+00
30	8.86000000E-02	1.98000000E-01	1.36230000E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 14

ALPHA	CHREF	CN	CA
0	6.27727327E-03	-1.06512190E-02	1.70274926E+00
1	9.89410952E-03	-1.79900054E-03	1.70233040E+00
2	1.34787561E-02	6.98194047E-03	1.70109039E+00
3	1.70800835E-02	1.56277442E-02	1.69903659E+00
4	2.04290502E-02	2.40503113E-02	1.69615365E+00
5	2.37396057E-02	3.22344989E-02	1.69245384E+00
6	2.69098803E-02	4.01001017E-02	1.68793927E+00
7	2.99272333E-02	4.76185565E-02	1.68261783E+00
8	3.27644580E-02	5.47643180E-02	1.67649521E+00
9	3.54307230E-02	6.15268627E-02	1.66957807E+00
10	3.79248814E-02	6.79812884E-02	1.66187723E+00
11	4.02381234E-02	7.39084851E-02	1.65339968E+00
12	4.23946778E-02	7.95768980E-02	1.64415054E+00
13	4.44129144E-02	8.49410363E-02	1.63415910E+00
14	4.63092785E-02	9.00073940E-02	1.62341951E+00
15	4.81127778E-02	9.48088174E-02	1.61195884E+00
16	4.98542098E-02	9.94247070E-02	1.59976713E+00
17	5.15672861E-02	1.03870974E-01	1.58688316E+00
18	5.32875445E-02	1.09448574E-01	1.57331464E+00
19	5.50516960E-02	1.14465870E-01	1.55907011E+00
20	5.68893398E-02	1.19863622E-01	1.54419892E+00
21	5.88530990E-02	1.25141390E-01	1.52867128E+00
22	6.09400003E-02	1.31014223E-01	1.51253784E+00
23	6.32475082E-02	1.37329358E-01	1.49581094E+00
24	6.57200397E-02	1.44144394E-01	1.47850994E+00
25	6.84321098E-02	1.51805320E-01	1.46065926E+00
26	7.13738304E-02	1.59445129E-01	1.44227218E+00
27	7.45589307E-02	1.67982672E-01	1.42337990E+00
28	7.79942033E-02	1.77172127E-01	1.40400174E+00
29	8.16429282E-02	1.86892701E-01	1.38410217E+00
30	8.55059002E-02	1.97146870E-01	1.36380503E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 15

ALPHA	CMREF	CN	CA
0	6.11280209E-03	-9.22508906E-03	1.70976401E+00
1	9.65174016E-03	-7.17037276E-04	1.70934082E+00
2	1.31600761E-02	7.72563359E-03	1.70807179E+00
3	1.66082137E-02	1.60397679E-02	1.70595844E+00
4	1.99685376E-02	2.41665919E-02	1.70300337E+00
5	2.32163275E-02	3.20537349E-02	1.69921016E+00
6	2.63305825E-02	3.96570522E-02	1.69458345E+00
7	2.92947319E-02	4.69421943E-02	1.68912888E+00
8	3.20972088E-02	5.38858722E-02	1.68285304E+00
9	3.47318690E-02	6.04767799E-02	1.67576364E+00
10	3.71982436E-02	6.67161462E-02	1.66786930E+00
11	3.95016148E-02	7.26178951E-02	1.65917963E+00
12	4.16529145E-02	7.82084120E-02	1.64970322E+00
13	4.36684468E-02	8.35259204E-02	1.63945762E+00
14	4.55694440E-02	8.86194864E-02	1.62844931E+00
15	4.73814677E-02	9.35476818E-02	1.61669369E+00
16	4.91336741E-02	9.83769451E-02	1.60420511E+00
17	5.08579648E-02	1.03179688E-01	1.59099876E+00
18	5.25880494E-02	1.08032208E-01	1.57709073E+00
19	5.43584475E-02	1.13012462E-01	1.56249799E+00
20	5.62034600E-02	1.18197780E-01	1.54723829E+00
21	5.81561413E-02	1.23662575E-01	1.53133024E+00
22	6.02473039E-02	1.29476125E-01	1.51479322E+00
23	6.25045837E-02	1.35700495E-01	1.49764737E+00
24	6.49515960E-02	1.42388658E-01	1.47991358E+00
25	6.76072071E-02	1.49582874E-01	1.46161348E+00
26	7.04849433E-02	1.57313373E-01	1.44276931E+00
27	7.35925550E-02	1.65597385E-01	1.42340400E+00
28	7.69317505E-02	1.74438546E-01	1.40354136E+00
29	8.04981049E-02	1.83826698E-01	1.38320537E+00
30	8.42811501E-02	1.93738084E-01	1.36242087E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 16

ALPHA	CMREF	CN	CA
0	5.76046005E-03	-7.57700879E-03	1.71770458E+00
1	9.25620773E-03	5.63640013E-04	1.71726963E+00
2	1.27222074E-02	8.64661755E-03	1.71596530E+00
3	1.61300980E-02	1.66143498E-02	1.71379310E+00
4	1.94532042E-02	2.44161868E-02	1.71075594E+00
5	[illegible]	[illegible]	[illegible]
6	2.57531444E-02	3.93299722E-02	1.70210107E+00
7	2.86930347E-02	4.63759907E-02	1.69647550E+00
8	3.14779009E-02	5.31156847E-02	1.69004829E+00
9	3.40993000E-02	5.95345016E-02	1.68275870E+00
10	[illegible]	[illegible]	[illegible]
11	3.88604669E-02	7.14570124E-02	1.66571351E+00
12	4.10147790E-02	7.69049143E-02	1.65597863E+00
13	4.30371200E-02	8.22734404E-02	1.64544309E+00
14	4.49480310E-02	8.73008424E-02	1.63412061E+00
15	[illegible]	[illegible]	[illegible]
16	4.85370336E-02	9.71960013E-02	1.60921020E+00
17	5.02736930E-02	1.01900163E-01	1.59563460E+00
18	5.20143420E-02	1.06871123E-01	1.58124101E+00
19	5.37921073E-02	1.11809722E-01	1.56634328E+00
20	[illegible]	[illegible]	[illegible]
21	5.75896035E-02	1.22408484E-01	1.53430876E+00
22	5.96703420E-02	1.28291767E-01	1.51731108E+00
23	6.19000570E-02	1.34380808E-01	1.49960920E+00
24	6.43282020E-02	1.40920306E-01	1.48146828E+00
25	[illegible]	[illegible]	[illegible]
26	6.97750670E-02	1.55424031E-01	[illegible]
27	7.28234202E-02	1.63619910E-01	1.42330120E+00
28	7.60920436E-02	1.71960573E-01	1.40290421E+00
29	7.95740179E-02	1.80807843E-01	1.38200400E+00
30	8.32676100E-02	1.90360109E-01	1.36070210E+00

APPENDIX (Sheet 8 of 11)

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 17

ALPHA	CMREF	CN	CA
0	5.25101155E-03	-5.74500664E-03	1.72560454E+00
1	8.72999845E-03	2.00791321E-03	1.72515684E+00
2	1.21800875E-02	9.70973387E-03	1.72381428E+00
3	1.55733235E-02	1.73111064E-02	1.72157850E+00
4	1.88836083E-02	2.47641280E-02	1.71845221E+00
5	2.20875567E-02	3.20339317E-02	1.71443924E+00
6	2.51652705E-02	3.90801193E-02	1.70954446E+00
7	2.81010036E-02	4.58779947E-02	1.70377385E+00
8	3.08837002E-02	5.24095574E-02	1.69713443E+00
9	3.35073882E-02	5.86662269E-02	1.68963429E+00
10	3.59714149E-02	6.46492733E-02	1.68128257E+00
11	3.82805197E-02	7.03699415E-02	1.67208944E+00
12	4.04447383E-02	7.58492633E-02	1.66206611E+00
13	4.24791440E-02	8.11175629E-02	1.65122479E+00
14	4.44074308E-02	8.62136703E-02	1.63957869E+00
15	4.62413536E-02	9.11838644E-02	1.62714198E+00
16	4.80200392E-02	9.60805783E-02	1.61392984E+00
17	4.97691917E-02	1.00960906E-01	1.59995835E+00
18	5.15202139E-02	1.05884952E-01	1.58524453E+00
19	5.33092725E-02	1.10914079E-01	1.56980632E+00
20	5.51563345E-02	1.16109100E-01	1.55366252E+00
21	5.71042049E-02	1.21528473E-01	1.53683280E+00
22	5.91775933E-02	1.27226553E-01	1.51933764E+00
23	6.14022392E-02	1.33251952E-01	1.50119843E+00
24	6.38001211E-02	1.39646055E-01	1.48243719E+00
25	6.63087739E-02	1.46441744E-01	1.46307681E+00
26	6.91807357E-02	1.53662359E-01	1.44314088E+00
27	7.21831399E-02	1.61320932E-01	1.42265368E+00
28	7.53974047E-02	1.69419720E-01	1.40164817E+00
29	7.88194496E-02	1.77950047E-01	1.38012596E+00
30	8.24391782E-02	1.86892456E-01	1.35813726E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 18

ALPHA	CMREF	CN	CA
0	4.61679264E-03	-3.76470634E-03	1.73585122E+00
1	8.10644713E-03	3.59209143E-03	1.73530932E+00
2	1.15674553E-02	1.09053580E-02	1.73480420E+00
3	1.49721007E-02	1.81340447E-02	1.73169755E+00
4	1.82944982E-02	2.52308090E-02	1.72847217E+00
5	2.15114392E-02	3.21073669E-02	1.72433119E+00
6	2.46031530E-02	3.89486984E-02	1.71926206E+00
7	2.75839670E-02	4.55010902E-02	1.71332085E+00
8	3.03528341E-02	5.18294760E-02	1.70647006E+00
9	3.29937192E-02	5.79267377E-02	1.69874077E+00
10	3.54750179E-02	6.37948861E-02	1.69012431E+00
11	3.78037837E-02	6.94411469E-02	1.68063970E+00
12	3.99871384E-02	7.48858668E-02	1.67029073E+00
13	4.20498034E-02	8.01537974E-02	1.65911376E+00
14	4.39840150E-02	8.52780020E-02	1.64709044E+00
15	[illegible]	[illegible]	[illegible]
16	4.76355923E-02	9.52549600E-02	1.62063669E+00
17	4.93007862E-02	1.00204367E-01	1.60622227E+00
18	5.11634076E-02	1.05190512E-01	1.59104208E+00
19	5.29541914E-02	1.10267200E-01	1.57511447E+00
20	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	1.54107979E+00
22	5.86365966E-02	1.26642713E-01	1.52300009E+00
23	6.10539664E-02	1.32467394E-01	1.50433184E+00
24	6.34392064E-02	1.38784422E-01	1.48407596E+00
25	[illegible]	[illegible]	[illegible]
26	[illegible]	1.52210514E-01	1.44443397E+00
27	7.17497004E-02	1.59825137E-01	1.42329736E+00
28	7.49278101E-02	1.67203183E-01	1.40161777E+00
29	7.83074673E-02	1.75244794E-01	1.37942150E+00
30	8.18707395E-02	1.83632952E-01	1.35673580E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 19

ALPHA	CMREF	CN	CA
0	3.87014079E-03	-1.65028937E-03	1.74574580E+00
1	7.38874016E-03	5.29206790E-03	1.74526910E+00
2	1.08786541E-02	1.22000036E-02	1.74383959E+00
3	1.43121233E-02	1.90402841E-02	1.74145899E+00
4	1.76632120E-02	2.57820145E-02	1.73813022E+00
5	2.09086495E-02	3.23977172E-02	1.73385733E+00
6	2.40285897E-02	3.88643035E-02	1.72864553E+00
7	2.70072653E-02	4.51639096E-02	1.72250116E+00
8	2.98335164E-02	5.12845691E-02	1.71543171E+00
9	3.25011770E-02	5.72207017E-02	1.70744580E+00
10	3.50093077E-02	6.29734027E-02	1.69855315E+00
11	3.73622667E-02	6.85505229E-02	1.68876460E+00
12	3.95626178E-02	7.39645367E-02	1.67809207E+00
13	4.16458759E-02	7.92422013E-02	1.66694857E+00
14	4.36100994E-02	8.44040160E-02	1.65414817E+00
15	4.54853409E-02	8.94834993E-02	1.64098594E+00
16	4.72979722E-02	9.45143026E-02	1.62683808E+00
17	4.90769046E-02	9.95411891E-02	1.61196167E+00
18	5.08527272E-02	1.04598907E-01	1.59629486E+00
19	5.26567903E-02	1.09730992E-01	1.57985674E+00
20	5.45202605E-02	1.14978531E-01	1.56266733E+00
21	5.64731760E-02	1.20380934E-01	1.54474757E+00
22	5.85435319E-02	1.25974737E-01	1.52611929E+00
23	6.07584215E-02	1.31792483E-01	1.50680521E+00
24	6.31332610E-02	1.37861713E-01	1.48682883E+00
25	6.56911200E-02	1.44204088E-01	1.46621450E+00
26	6.84421782E-02	1.50834690E-01	1.44498739E+00
27	7.13933261E-02	1.57781490E-01	1.42317322E+00
28	7.45459194E-02	1.64985038E-01	1.40079870E+00
29	7.78956967E-02	1.72498348E-01	1.37789104E+00
30	8.14328014E-02	1.80287007E-01	1.35447814E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 20

ALPHA	CMREF	CN	CA
0	3.02979786E-03	5.75883534E-04	1.75610075E+00
1	6.59444051E-03	7.09200484E-03	1.75581482E+00
2	1.01301502E-02	1.35036738E-02	1.75413043E+00
3	1.36087943E-02	2.00254159E-02	1.75148027E+00
4	1.70041757E-02	2.63945387E-02	1.74824305E+00
5	2.02927487E-02	3.26788083E-02	1.74383894E+00
6	2.34544074E-02	3.88372437E-02	1.73844933E+00
7	2.64731435E-02	4.48080844E-02	1.73210478E+00
8	2.93375767E-02	5.07927038E-02	1.72480500E+00
9	3.20413943E-02	5.65809427E-02	1.71658090E+00
10	3.45833363E-02	6.22105294E-02	1.70737088E+00
11	3.69677579E-02	6.77233480E-02	1.69720904E+00
12	3.92040860E-02	7.31102807E-02	1.68624087E+00
13	4.13040481E-02	7.84187803E-02	1.67432020E+00
14	4.32945173E-02	8.36205348E-02	1.66152477E+00
15	4.51904004E-02	8.87710236E-02	1.64781111E+00
16	4.70214204E-02	9.38808453E-02	1.63332000E+00
17	4.88157002E-02	9.90071444E-02	1.61790370E+00
18	5.06060833E-02	1.04141660E-01	1.60178054E+00
19	5.24179108E-02	1.09337027E-01	1.58461208E+00
20	5.42883967E-02	1.14628838E-01	1.56470838E+00
21	5.62455880E-02	1.20014957E-01	1.54859074E+00
22	5.83174527E-02	1.25561677E-01	1.52932454E+00
23	6.05291309E-02	1.31260820E-01	1.50938122E+00
24	6.29071110E-02	1.37166405E-01	1.48875300E+00
25	6.54532064E-02	1.43268799E-01	1.46769883E+00
26	6.81931402E-02	1.49580677E-01	1.44854927E+00
27	7.11342744E-02	1.56040107E-01	1.42302041E+00
28	7.42779089E-02	1.62839042E-01	1.39992000E+00
29	7.76042708E-02	1.69700851E-01	1.37620000E+00
30	8.11200044E-02	1.76949281E-01	1.35209120E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 21

ALPHA	CMREF	CN	CA
0	2.10872682E-03	2.89679435E-03	1.76687069E+00
1	5.73419229E-03	8.97846507E-03	1.76636230E+00
2	9.33014940E-03	1.50441912E-02	1.76483775E+00
3	1.28680310E-02	2.10785885E-02	1.76229890E+00
4	1.63211230E-02	2.70673752E-02	1.75874884E+00
5	1.96654231E-02	3.29978803E-02	1.75419189E+00
6	2.28804059E-02	3.88595805E-02	1.74863362E+00
7	2.59496955E-02	4.46440922E-02	1.74208078E+00
8	2.88615990E-02	5.03462860E-02	1.73454137E+00
9	3.16095016E-02	5.59637130E-02	1.72602457E+00
10	3.41921030E-02	6.14971361E-02	1.71654075E+00
11	3.66134910E-02	6.69504821E-02	1.70610148E+00
12	3.88830485E-02	7.23307715E-02	1.69471946E+00
13	4.10151964E-02	7.76479496E-02	1.68240857E+00
14	4.30289807E-02	8.29146220E-02	1.66918381E+00
15	4.49475151E-02	8.81457037E-02	1.65500128E+00
16	4.67972970E-02	9.33579895E-02	1.64005819E+00
17	4.86074163E-02	9.85696417E-02	1.62419283E+00
18	5.04086816E-02	1.03799746E-01	1.60748452E+00
19	5.22376809E-02	1.09087535E-01	1.58995362E+00
20	5.41108077E-02	1.14391996E-01	1.57162149E+00
21	5.60735133E-02	1.19791173E-01	1.55251046E+00
22	5.81488678E-02	1.25281423E-01	1.53264381E+00
23	6.03672441E-02	1.30877867E-01	1.51204579E+00
24	6.27352901E-02	1.36591913E-01	1.49074130E+00
25	6.52850595E-02	1.42432834E-01	1.46875666E+00
26	6.80239605E-02	1.48406428E-01	1.44611836E+00
27	7.09588507E-02	1.54514970E-01	1.42285407E+00
28	7.40910380E-02	1.60757057E-01	1.39899213E+00
29	7.74161470E-02	1.67127559E-01	1.37456161E+00
30	8.09242029E-02	1.73017668E-01	1.34959228E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 22

ALPHA	CMREF	CN	CA
0	1.11753379E-03	5.30247376E-03	1.77708575E+00
1	4.81696253E-03	1.09401272E-02	1.77746869E+00
2	8.40536540E-03	1.65715961E-02	1.77580601E+00
3	1.20946781E-02	2.21909233E-02	1.77326373E+00
4	1.56171116E-02	2.77925908E-02	1.76959701E+00
5	1.90280583E-02	3.33717687E-02	1.76490033E+00
6	2.23064200E-02	3.89244940E-02	1.75916941E+00
7	2.54353612E-02	4.44476875E-02	1.75238129E+00
8	2.84027084E-02	4.99391085E-02	1.74459400E+00
9	3.12017876E-02	5.53985044E-02	1.73579762E+00
10	[illegible]	6.08284473E-02	[illegible]
11	3.62497971E-02	6.62244472E-02	1.71521964E+00
12	3.84608390E-02	7.15957188E-02	1.70346363E+00
13	4.07650375E-02	7.69443981E-02	1.69074826E+00
14	4.28047089E-02	8.22736933E-02	1.67700887E+00
15	[illegible]	[illegible]	[illegible]
16	4.66184864E-02	9.29111301E-02	1.64700610E+00
17	4.84448816E-02	9.82202760E-02	1.63041940E+00
18	5.02943200E-02	1.03557990E-01	1.61330219E+00
19	5.20978601E-02	1.08903870E-01	1.59525510E+00
20	[illegible]	1.14276390E-01	[illegible]
21	[illegible]	1.19676708E-01	[illegible]
22	5.80300164E-02	1.25110664E-01	1.53600217E+00
23	6.02475340E-02	1.30590094E-01	1.51470720E+00
24	6.26239759E-02	1.36127440E-01	1.49270283E+00
25	[illegible]	1.41728998E-01	[illegible]
26	[illegible]	1.47330041E-01	1.44640366E+00
27	7.08857072E-02	1.53208144E-01	1.42286473E+00
28	7.39942770E-02	1.58727817E-01	1.39861000E+00
29	7.73173976E-02	1.64480952E-01	1.37270530E+00
30	8.08249649E-02	1.70290887E-01	1.34609984E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 25

ALPHA	CMREF	CN	CA
0	-2.19628482E-03	1.29299838E-02	1.81313787E+00
1	1.78533397E-03	1.71928980E-02	1.81255916E+00
2	5.73363607E-03	2.14805268E-02	1.81082613E+00
3	9.61634344E-03	2.58167950E-02	1.80794008E+00
4	1.34032236E-02	3.02238329E-02	1.80390459E+00
5	1.70670337E-02	3.47216212E-02	1.79872443E+00
6	2.05843730E-02	3.93269083E-02	1.79240605E+00
7	2.39344179E-02	4.40578701E-02	1.78495710E+00
8	2.71095158E-02	4.89083410E-02	1.77638666E+00
9	3.00956209E-02	5.38979602E-02	1.76670517E+00
10	3.28925578E-02	5.90214536E-02	1.75592443E+00
11	3.55041041E-02	6.42738085E-02	1.74405756E+00
12	3.79398904E-02	6.96452929E-02	1.73111903E+00
13	4.02151200E-02	7.51216672E-02	1.71712460E+00
14	4.23501155E-02	8.06845322E-02	1.70209133E+00
15	4.43697083E-02	8.63118021E-02	1.68603751E+00
16	4.63074871E-02	9.19782885E-02	1.66898273E+00
17	4.81799287E-02	9.76563781E-02	1.65094775E+00
18	5.00354383E-02	1.03316783E-01	1.63195455E+00
19	5.19073268E-02	1.08929338E-01	1.61202624E+00
20	5.38177572E-02	1.14463829E-01	1.59118717E+00
21	5.58114914E-02	1.19890816E-01	1.56946267E+00
22	5.79158689E-02	1.25182435E-01	1.54687922E+00
23	6.01578499E-02	1.30313147E-01	1.52346435E+00
24	6.25611495E-02	1.35240624E-01	1.49924056E+00
25	6.51444916E-02	1.40005327E-01	1.47425538E+00
26	6.79212027E-02	1.44537990E-01	1.44852125E+00
27	7.08987064E-02	1.48632970E-01	1.42207552E+00
28	7.40785501E-02	1.52099464E-01	1.39495842E+00
29	7.74557137E-02	1.56731382E-01	1.36717898E+00
30	8.10193015E-02	1.60332281E-01	1.33879509E+00

GEMINI AERODYNAMIC CHARACTERISTICS

MACH NO. = 30

ALPHA	CMREF	CN	CA
0	-8.49792828E-03	2.65295168E-02	1.86867843E+00
1	-3.91731314E-03	2.83078301E-02	1.86788664E+00
2	4.22779308E-04	3.03259403E-02	1.86580018E+00
3	5.04308429E-03	3.24210011E-02	1.86265503E+00
4	9.42688549E-03	3.47446839E-02	1.85777864E+00
5	[illegible]	[illegible]	[illegible]
6	1.76353475E-02	4.03234762E-02	1.84448844E+00
7	2.14483983E-02	4.36742280E-02	1.83681984E+00
8	2.50423031E-02	4.76414082E-02	1.82580094E+00
9	2.84048744E-02	5.16308413E-02	1.81464666E+00
10	[illegible]	[illegible]	[illegible]
11	3.44468888E-02	6.12999139E-02	1.78841964E+00
12	3.71242911E-02	6.67137909E-02	1.77342059E+00
13	3.96085127E-02	7.24581408E-02	1.75720884E+00
14	4.19187944E-02	7.84719884E-02	1.73978316E+00
15	[illegible]	[illegible]	[illegible]
16	4.61048897E-02	9.10074830E-02	1.70161230E+00
17	4.80488830E-02	9.73842948E-02	1.68031091E+00
18	4.99848083E-02	1.03613609E-01	1.65849099E+00
19	5.19048803E-02	1.09742819E-01	1.63940328E+00
20	[illegible]	[illegible]	[illegible]
21	5.59987497E-02	1.21004017E-01	[illegible]
22	5.80943380E-02	1.26000839E-01	1.55999108E+00
23	6.03091001E-02	1.30890410E-01	1.53270894E+00
24	6.29370320E-02	1.34501430E-01	[illegible]
25	[illegible]	[illegible]	[illegible]
26	6.83942333E-02	1.40294107E-01	1.44491088E+00
27	7.15070180E-02	1.42112203E-01	1.41526198E+00
28	7.48301503E-02	1.43141358E-01	[illegible]
29	7.83840878E-02	1.43835829E-01	1.35164082E+00
30	8.21439041E-02	1.43169380E-01	1.31070864E+00

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